SNOW SAFETY GUIDE NUMBER 2

Instrumentation

for Snow, Weather and Avalanche Observations

U. S. DEPT. OF AGRICULTURE
FOREST SERVICE

WASATCH NATIONAL FOREST
APRIL 1970

ALTA AVALANCHE STUDY CENTER

Revised August 1973

The Snow Safety Guides

Since the USDA Handbook 194 "Snow Avalanches" was published in 1961, there has developed an increasing need for additional publications on snow safety. Part of this is the result of new techniques, equipment and policies which have evolved since 1961, and part of the need stems from a steady increase in snow safety problems accompanying the growth of the winter sports industry.

In order to provide thorough and up-to-date treatment of specific topics which received only limited discussion in Handbook 194, the series of publications known as "Snow Safety Guides" has been established. These will, in essence, constitute supplements and revisions of Handbook 194. Various individuals in National Forest Administration and Research throughout the Forest Service will contribute material for the Guides. Editorial supervision will be exercised by the Alta Avalanche Study Center on the Wasatch National Forest.

The following Guides have now been published:

Snow Safety Guide No. 1--Modern Avalanche Rescue (1968)

Snow Safety Guide No. 2--Instrumentation for Snow, Weather and Avalanche Observations (1970) (Revised, 1973)

Edward R. LaChapelle
Alta Avalanche Study Center

The Alta Avalanche Study Center was discontinued in 1972. Requests for copies of this publication should be sent to: Rocky Mountain Forest and Range Experiment Station, 240 West Prospect, Fort Collins, Colorado 80521.

INTRODUCTION

There have been an increasing number of requests in recent years for information on instrument specifications for snow and avalanche observations in new ski areas. The recent adoption by the Forest Service of uniform standards and requirements for snow, avalanche and weather records in Class A* winter sports areas on National Forest land has accelerated the demand for this information. This manual has been prepared specifically to answer the questions of what kind of instruments have been found satisfactory, how much they cost, where they can be ordered, and how they should be installed. The text provides details and explanatory background material on the basic measurements and methods. Appendix A lists specifications, costs and typical sources for all instrumentation requirements likely to be encountered by a Class A ski area with a full-time avalanche observer. Not all of the items listed will be required in all areas. We have tried to list, if anything, too much information rather than too little. For convenience of Government purchasing agents, Appendix B lists current recommendations for a complete complement of major instruments for a typical Class A ski area, together with their sources, costs, Federal Stock Numbers where applicable, and availability under GSA contracts. Exact requirements for a given area will vary with circumstances, including administrative problems, terrain and climate. National Forest personnel should consult with the Rocky Mountain Forest and Range Experiment Station before making major equipment acquisitions.

The state of the art in weather instrumentation is constantly evolving. A few years hence, newer and better instruments than the ones described here may be available. When this time comes, a revised manual will be issued, but only after new instruments and procedures have been proven reliable and adaptable to the peculiar environmental requirements of a mountain winter. The standard for making the present recommendations is proven reliability in the face of such adverse agents as high wind, snow, rime, and low temperature. Not every instrument mentioned here has been tested under every conceivable condition, but none is untried. Others may exist which will perform satisfactorily but have not come to our attention. To insure satisfactory performance in new areas and under unforeseeable conditions of installation, we can only rely on experience in choosing the types of equipment to use.

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*Class A ski areas on National Forest lands are those with extensive or frequent avalanche hazards. Class B areas have few or infrequent avalanche hazards which do not warrant a continuous snow safety program. Class C areas are free of avalanche hazard.

Snow Safety Guide No. 2 is not intended to be an operations manual or to instruct observers. The basic information on techniques can be found in Chapter 6 of "Snow Avalanches" (USDA Handbook No. 194). A later Snow Safety Guide will discuss modern methods and techniques of observation in more detail.

Much useful information on weather observations and associated instrumentation will also be found in two other publications which should be available to snow and avalanche observers. One is "Weather Bureau Observing Handbook No. 2, Substation Observations", First Edition 1970 (U. S. Government Printing Office, Washington, D.C., 75¢). The other is Agriculture Handbook No. 224, "Field Manual for Research in Agricultural Hydrology" (U. S. Government Printing Office, Washington, D.C.). Another useful publication, which describes international standards for observing and reporting snow, is IASH-UNESCO Joint Publication No. 6, "Seasonal Snow Cover". This manual is available for $3.00 from the General Secretary, International Association of Scientific Hydrology, Braamstraat 61, Gentbrugge, Belgium.

This instrumentation manual has been compiled and edited by Edward R. LaChapelle, Avalanche Hazard Forecaster, Wasatch National Forest. Extensive contributions and suggestions have been made by M. Martinelli, Jr., Arthur Judson, R. A. Schmidt, and Knox Williams of the Rocky Mountain Forest and Range Experiment Station.

SECTION 1--WIND

A record of wind direction and velocity at the avalanche fracture zone is essential to snow safety decisions. This record is also expensive and technically the most difficult to obtain of all avalanche observations. Accurate, rugged instrumentation is indispensable. It is extremely difficult for an observer even fully exposed to the elements to estimate average wind velocity; his subjective impressions of peak velocities are also apt to be in error. Guessing velocities for a distant ridge during the midnight hours is impossible. Prevailing wind direction is usually much more obvious to a resident observer, either from direct observations or from later evidence of snowdrifts and cornices. But for wind direction as well, the obstacles of darkness and distance can only be overcome by instruments.

Low-elevation wind regimes are often poorly representative of ridge-top conditions. The most severe instrumentation demands are made by those areas with a large difference in elevation, and consequently in storm and snow conditions, between ridge-top and valley floor. The anemometer and wind vane must be located high on the mountain at a place representative of the starting zones of the most frequent and troublesome avalanches. Where avalanches are present on several exposures, ridge crest locations are usually best. The output from the sensors must be transmitted to and recorded at the nearest convenient site accessible to the area administrator without use of the lift system. He must be able to determine current and recent wind conditions at night, before the lifts operate in the morning, and especially during those times when lift operation is halted by high winds or avalanche hazard. Data transmission by wire or radio telemetry is essential. It may be omitted where overnight residence of lift operators or ski patrolmen at a mountain-top facility is routine. In such instances, the recorder can be located near the wind sensors and the read-out verbally telephoned to the valley.

Wire lines for wind data transmission must provide reliable service in adverse mountain weather, including deep snow, icing, and high winds. Incorporation of extra circuits in lift control cables is satisfactory and the least expensive method. If this is not possible, separate wires must be installed to professional telephone standards. Improvised or patchwork cables are highly unsatisfactory. Contract installation by qualified professional telephone linemen is strongly recommended. Buried cable is the best but the cable cost is higher and the possibility of damage from bulldozer activity must be considered (this is a frequent problem in developing ski areas). Overhead wires on poles are sometimes preferred, but wire strength, supports and pole spacing must all be designed for the severe winter environment. Cables laid on the ground will invariably be damaged by snow creep and

rodents. The number and size of conductors required vary with the wind system used (see individual specifications below). Where appreciable current must be carried, the conductor size will be dictated by length of cable, type of instrument, and power supply voltage. Because cable cost may often be the dominant factor in a wind system installation, the number and size of conductors have to be carefully considered in relation to the type of equipment selected. A general rule cannot be established to cover all situations. Study the specifications set forth below and seek professional advice before selecting a new system.

24-hour Wind Run

The minimum climatological record is the total miles of wind past an anemometer each 24 hours. This record is worthless for avalanche hazard forecasting, and is not worth the expense and trouble to install and maintain.

Continuous Wind Speed and Direction (Analog System)

A continuous record of wind speed and direction is necessary for proper snow safety evaluation and for research purposes as well. The standard system for obtaining this record at U. S. Forest Service Class A ski areas is the analog direction and speed recorder. Such a system gives maximum information because the continually changing values of wind speed and direction are recorded and displayed. Speed information comes from an anemometer which is designed as an electrical generator whose output voltage is proportional to speed of rotation and hence to wind speed. This output is continually traced on a strip chart by a recording voltmeter. A similar trace shows direction, the output voltage from a potentiometer being determined by the orientation of the vane. Figure 1 shows the character of these records obtained from a dual-channel recorder which displays speed and direction side-by-side on a single chart.

Two types of anemometers have been found suitable for analog winter wind records in the mountains. One is an alternating current generator (A25a)* and the other is a direct current generator (A25b); both have advantages and disadvantages; both can be connected to the same kind of recorder. The direct-current type is the standard for Class A ski areas and is the only one which will be described here.

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*Numbers in parentheses refer to the equipment listed in Appendices A and B.

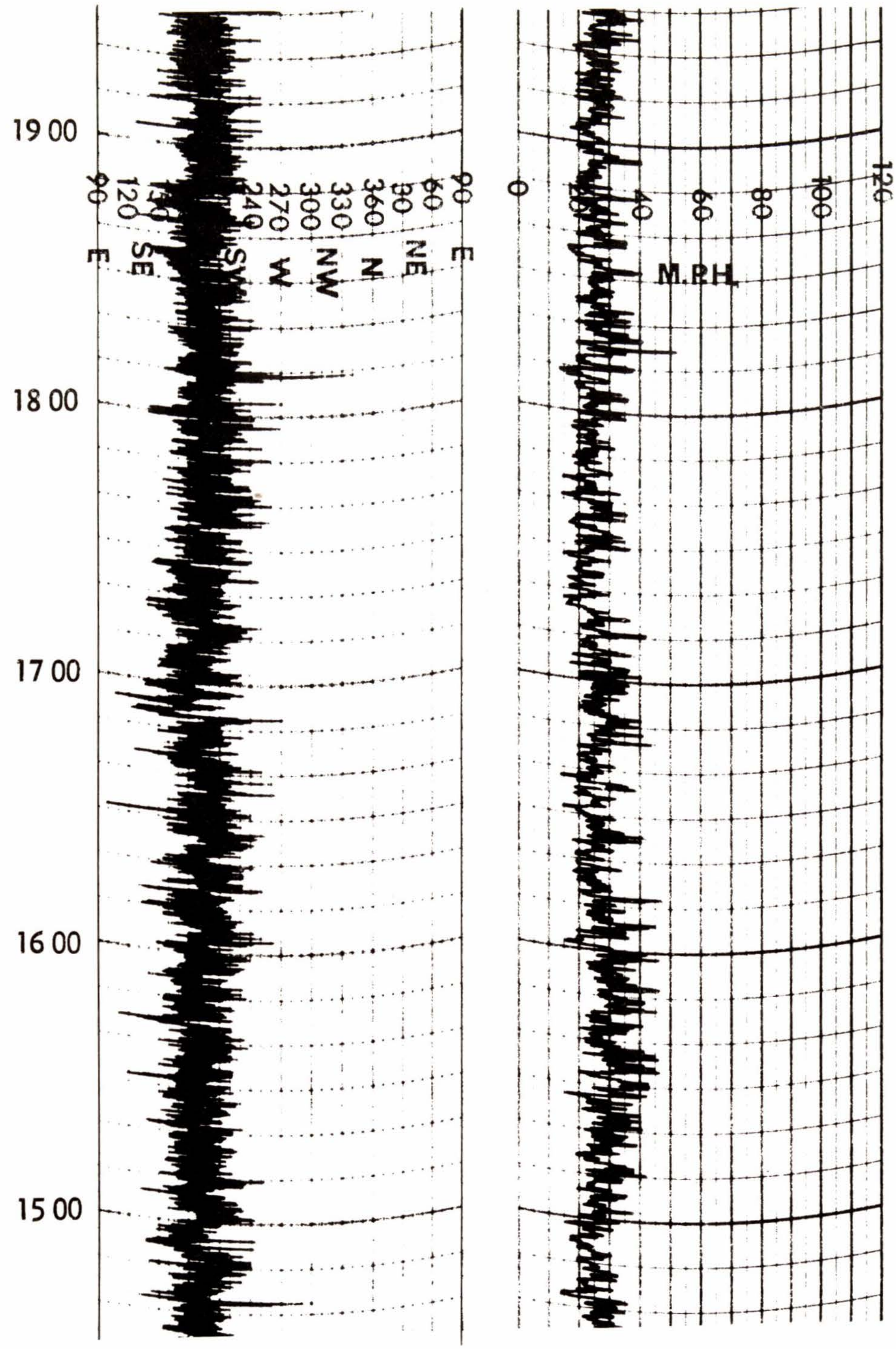

Figure 1. Example of analog wind direction and speed record, using a generating anemometer, resistance vane and recording dual-channel milliammeter.

The DC generator anemometer (A25b) is less responsive to rapid speed changes, but offers the distinct advantage of a linear relationship between output voltage and wind velocity. Circuitry and calibration procedure for this unit are given in Appendix C. This type of anemometer is recommended for most installations, but special problems may require an alternate selection (see discussion under Maintenance).

The analog wind vane (B2) uses a 360° stepping potentiometer attached to the vane shaft. This gives a varying resistance whose value is determined by orientation of the vane. At one point on the circle there is a jump from zero to maximum resistance. The vane body should be oriented so that this jump occurs at the most infrequent wind direction. Appendix C gives circuit and calibration procedure for the resistance-type wind vane. Accuracy of this type of wind direction record depends on accurate voltage regulation of the power supply. See Figure 18 for circuit details.

The analog style of wind record requires two conductors between anemometer and recorder, and three conductors between the wind vane and recorder. The saving of six conductors over those required for the contact vane can offer such a substantial saving in the cost of a long cable that this system often will be the most economical in spite of the higher cost of the components. Especially for long lines, where resistance of a single conductor becomes an appreciable part (say 1/10th) of the input circuit resistance to the recorder (not the meter movement resistance) then separate circuits (five conductors in all) should be used for anemometer and vane to avoid interaction between the two.

The analog system for wind recording described here is specified as standard for new installations in Class A ski area, unless special problems dictate otherwise. The detailed record of gustiness, peak velocities, and the character and changes in wind patterns provide much useful information for avalanche hazard forecasting that is not available from a digital (contact anemometer) record.

Continuous Wind Speed and Direction (Digital System)

Because a number of Class A ski areas already have digital systems using contact anemometers and vanes, this latter system will also be described in detail. The ultimate goal of the snow and avalanche data reporting network, however, will be to install analog wind systems at all Class A areas.

The contact anemometer described above may be connected to a strip-chart operations (event) recorder. An operations recorder drives a clock-driven chart on which are inked lines, up to 20 on the heavy duty models (A28a). The pen drawing each line can be

deflected slightly by a solenoid, so that each line has two positions on the charts, depending on whether or not the solenoid is energized (See Figure 2). The one-mile anemometer contact can be wired to operate a solenoid (two conductors required). Several anemometers can be recorded simultaneously. Contact arcing causes a serious maintenance problem unless the circuit in Figure 3 is used. This solid-state relay completely eliminates inductive surge at the anemometer contacts, as well as the effects of losses introduced by line resistance. By thus reducing the required size of cable conductors, this circuit can lead to large savings on long wire lines.

The operations recorder can also record wind direction. A contact wind vane (A26) is used which closes any one of eight electrical contacts, depending on which cardinal direction of the compass the vane is indicating. Each contact is wired to a separate pen solenoid of the recorder. Figure 2 shows the character of the record obtained. A fully-operational direction record requires nine conductors in the telemetry cable--eight for the position contacts and one common return. This common return may also be used for one of the anemometer conductors, so a total of 10 conductors is required for speed and direction (12 if the circuit of Figure 3 is used with the anemometer). The number of conductors required can be reduced by sacrificing recorded wind directions, one conductor to a direction.

The heavy-duty operations recorder (A28a) demands considerable power. Each 6-volt solenoid draws approximately 0.25 ampere when energized. If wind direction is being recorded, at least one solenoid is always energized. An adequate DC power supply must be provided. A storage battery and charger (A39) connected to line power are desirable, for this permits a number of hours operation from the battery in case of power line failure. The charger described will operate the system without the battery.

The electrical contacts in the wind vane (A26) are much heavier than in the anemometer and normally can sustain the effects of contact arcing with less damage. The use of a capacitor or diode arc suppressor across the wind vane contacts will keep this problem to a minimum, although sound maintenance procedures cannot be ignored. It is possible to use the circuit of Figure 3, but a separate complete circuit is required for each contact.

The combination of contact anemometer/wind vane and spring-driven operations recorder has been proven reliable by many years of use and provides a satisfactory wind record for snow safety operations. The digital record it provides can be easily counted for transcription to the wall charts or other record forms. It also eliminates all calibration problems, for the calibration is fixed in the design of the anemometer. But the wind run record

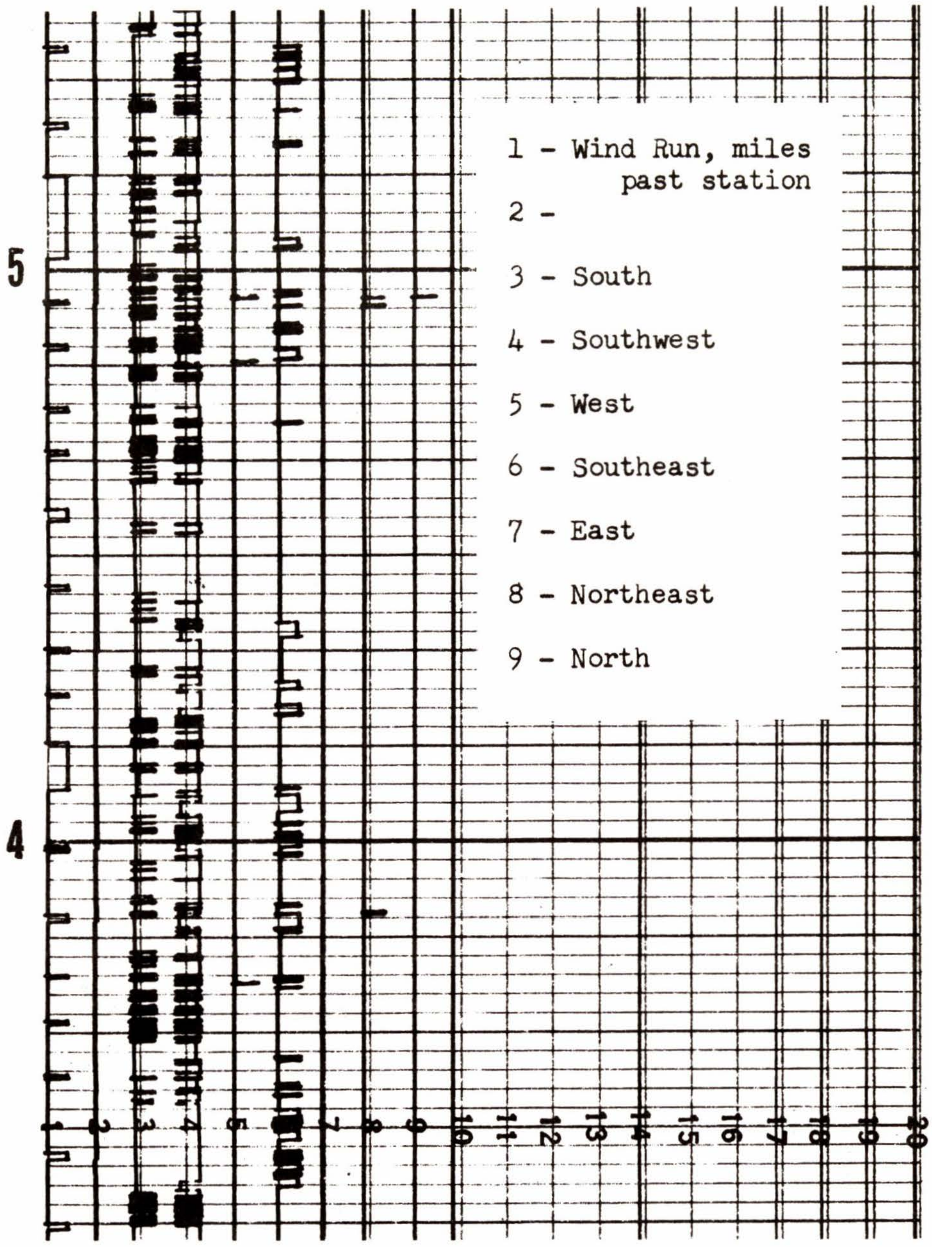

Figure 2. Example of digital wind direction and speed record using contact-type vane and anemometer and operations recorder. Large numerals alongside the left-hand chart margin are hours.

is basically a record of short-term average wind velocities, a consequence inherent in the anemometer construction. Thus it does not present a complete record of wind behavior.

An additional discussion of specific technical problems associated with wind systems will be found under Installation and Maintenance.

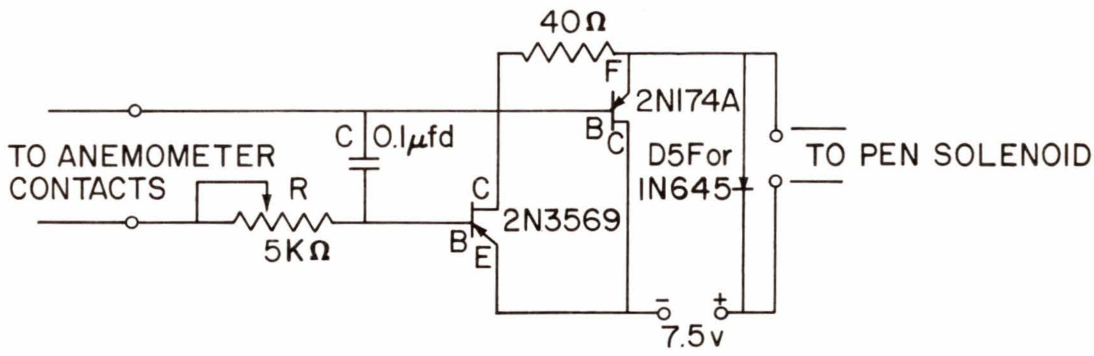

Figure 3. A solid-state relay used to switch the pen solenoid of an operations recorder. This circuit reduces current flowing through the anemometer contacts to about 0.1 ma and eliminates damage from contact arcing. It will function with a resistance up to 50,000 ohms in the anemometer circuit. Values of R and C should be adjusted to the smallest ones which will still eliminate solenoid trip from random line noise. These will vary with line conditions. Typical values are shown. The circuit will function at 6.3 volts, but the slightly elevated voltage is required to insure designed current in the solenoid. Total cost of the components is about $10. A separate circuit is required for each solenoid of the recorder. The anemometer contact circuit cannot be operated through lines which are also common to either side of the power supply. This same circuit can also be used to operate an electromechanical counter with a 6-volt coil drawing less than 500 ma.

AREA Berthoud Pass STA. NO. 100

MONTH Jan YEAR 73

U. S. FOREST SERVICE

MONTHLY SUMMARY OF WEATHER AND SNOW CONDITIONS

REVISED 10/71

Williams

OBSERVERS

DAY OF MONTH (8-9)	TIME OF OBSN. (10-13)	TEMPERATURE: 24 HOURS ENDING AT OBSERVATION: MAX °F (14-16)	MIN °F (17-19)	AT TIME OF OBSERVATION: AIR TEMP. °F (20-22)	20 CM BELOW SNOW SFC °C (23-25)	DEPTH OF SNOW ON THE GROUND* IN. (26-28)	PRECIPITATION*: NEW SNOW DEPTH 1/2 OF IN. (29-31)	WATER EQUIV. OF NEW SNOW 1/100 OF IN. (32-34)	WATER FROM RAIN 1/100 OF IN. (35-37)	NEW SNOW TYPE BY 6-HR PERIODS (1): 0-6 hrs (38)	06-12 (39)	12-18 (40)	18-24 (41)	INTENSITY BY 6-HR PERIODS (2): 0-6 hrs (42)	06-12 (43)	12-18 (44)	18-24 (45)	WIND DIRECTION AND SPEED*: SIX-HOUR AVERAGES, TIME PERIOD (ENTER 99 FOR VARIABLE DIRECTION): 00-06hrs DIR (00-36) (46-47)	MPH (48-49)	06-12 DIR (00-36) (50-51)	MPH (52-53)	12-18 DIR (00-36) (54-55)	MPH (56-57)	18-24 DIR (00-36) (58-59)	MPH (60-61)	FASTEST ONE-HOUR AVERAGE WIND DIRECTION AND SPEED: DIR (00-36) (62-63)	MPH (64-66)	STRATIGRAPHY: TEST SLOPES ONLY; FROM KEY(3), CHOOSE MOST SIGNIFICANT LAYER(S) BURIED 20-200CM BELOW SNOW SURFACE; EXPOSURE OF SLOPE: UPPER N (67)	E (68)	S (69)	W (70)	LOWER N (71)	E (72)	S (73)	W (74)	TEST SKIING RESULTS (4) (75)	EST. OF AVAL. HAZARD 0=none 1=low 2=borderline 3=high: AM (76)	PM (77)	CLOSURES (5) (78)	(79)	(80)	REMARKS (Use for clarifying statements about any entries, noting any unusual or interesting events. Please limit remarks to one line per day.)
1	0800	20	-5	-1	-8	50	.0	.0	.0									28	09	30	11	27	16	25	14	27	020	1	1							1	1	1				falling barometer
2	↓	25	-2	5	-8	50	.5	.T	.0						1	2	2	24	15	25	15	24	12	24	20	24	028										1	2				storm began about 0600
3	↓	24	10	12	-9	53	4.0	.30	.0		2	2		2	3	3	3	25	22	27	18	27	18	30	15	25	035					5					2	2				
4	↓	21	4	9	-8	63	11.0	.82	.0		3	2		3	3	3	2	30	18	28	22	30	24	30	20	27	027				8					3	3	3	3			
5	↓	18	-3	0	-9	70	8.5	.60	.0		2			2	2			33	15	33	18	30	16	30	12	31	020										3	2	3			snow ended near noon
6	↓	15	-10	-5	-10	70	.5	.02	.0									36	10	03	10	02	07	33	05	35	015										2	2				
7	↓	5	-18	-14	-12	70	.0	.0	.0									99	06	99	04	18	06	20	08	18	010										2	2				
8	↓	7	-14	-11	-12	69	.0	.0	.0								1	21	08	18	07	15	04	99	03	20	009									1	1	1				
9	↓	18	0	0	-11	69	.T	.T	.0									22	10	25	12	27	15	27	15	27	022										1	1				
10	↓	29	6	12	-9	68	.0	.0	.0									24	15	29	12	27	12	28	10	25	018									1	1	1				
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SUMS					-		.	.	.																																	
MEANS					-		.	.	.																																	

FOR KEYPUNCHING ONLY — COL 1 2 3 4 5 6 7

*	ELEVATION	LOCATION
SNOW STUDY PLOT	11,300	Q-12
ANEMOMETER	11,880	chairlift

(1) New snow types - record the *dominant* crystal type falling by 6-hour periods.
1 = aggregates or clusters of crystals, large snowflakes (stable)
2 = other (intermediate)
3 = needles, graupel, rimed spatial dendrites, and/or other moderately or heavily rimed crystals (unstable)

(2) Precipitation Intensity
Snow: 1 = very light, 2 = light, 3 = moderate, 4 = heavy, 5 = very heavy
Rain: 6 = light, 7 = mod, 8 = heavy

(3) Stratigraphy
1 = hoar, 2 = graupel, 3 = ice, 4 = large wet grains, 5 = other loose cohesionless grains, 6 = slush, 7 = fresh damp snow, 8 = combination of two or more, 9 = other

(4) Test skiing
1 = no cracking
2 = minor cracking
3 = major cracking
4 = slab release

(5) Closures
1 = road closed, 2 = ski area partly or wholly closed, 3 = ski touring closed or not rec., 4 = comb. 1 & 2, 5 = comb. 1 & 3, 6 = comb. 2 & 3, 7 = comb. 1, 2, & 3

Figure 3a. Example of standard Forest Service weather record chart, showing typical entries. An 80-column format is used to facilitate data reduction for computer use.

SECTION 2--AIR TEMPERATURE

An accurate temperature of the air is an elusive quantity. There are no instruments suitable to routine field use which measure this directly. All instruments in current use--thermometer, thermographs, temperature recorders--measure the temperature of a substance in the instrument, such as a mercury column, bimetallic element or gas in a closed system. Whether the temperature of this substance is the same as that of the surrounding air depends on the many complex factors affecting the heat balance of the sensor. Whether this surrounding air is at the same temperature as the free air in the vicinity is further a function of microclimate and environment. The finest precision thermometer is no better for measuring air temperature than the manner in which it is exposed.

The heat balance of a temperature sensor depends on convective and conductive heat exchange with the air, evaporation or condensation of moisture, and radiation, both visible and infrared. Ideally, it should depend only on heat exchange with the air; then the only errors would be due to lag in following rapid air temperature changes. Evaporation or condensation can cause very large errors, but these are usually transient. Temperature sensors are usually shielded from direct precipitation, but this cannot be eliminated entirely if a free flow of air is also allowed. The most persistent source of error is radiation. This can never be entirely eliminated, but it can be minimized by proper shielding. The most accurate air temperature measurements are made with sensors exposed to strong forced ventilation (aspiration), so that the heat exchange with the air dominates the other exchanges. Normal climatological (and snow-avalanche) air temperature sensors are non-aspirated and depend only on natural circulation from the wind to assure heat exchange with the air.

Temperature sensors should never be exposed to direct or reflected solar radiation. Further, they should be enclosed in a shield which in itself is reasonably close to the prevailing air temperature; otherwise infra-red heat exchange between sensor and shield wall will introduce error. The best shields are double-walled, the inner wall shielding the sensor and the outer wall shielding the inner one. A free circulation of air must be assured. The installation must be free from local influences of artificial heat sources or strong perturbations in the microclimate (chimney, asphalt paving, etc.).

Large air temperature variations occur close to the ground. These variations can be especially intense over a snow surface. The temperature sensor must be located above the major part of these variations. The minimum height above the ground is four feet; this is the standard for climatological observations. In

areas of deep winter snow cover, provision should be made to raise the instrument shelter up a pole or the side of a tower to maintain this spacing as the snow accumulates. (See Figure 4.) If this is not possible, an elevated site at least six feet above the maximum expected snow depth should be chosen. It is better to have the sensor too high than too low. In the case of remote-sensing temperature recorders (A18 and Figure 5), the sensor and shield can be located on a support attached to the building but extending at least six feet above the roof line and well away from chimneys or other heat sources. This does not meet climatological specifications, but is satisfactory for snow and avalanche observations and offers the convenience of having the recorder inside the building for easy inspection.

The standard instrument shelter, large enough to hold a complete thermograph as well as thermometers or other instruments, is the U. S. Weather Bureau louvered wooden shelter (A19). This provides adequate ventilation and reasonable radiation shielding. For maximum effectiveness (and for preservation as well), it should be kept painted inside and out with a good grade of dead white paint. The normal base is adequate in areas of shallow snow, but provision must be made to raise it the prescribed distance above accumulating deep snow. Location at a windy site assures good ventilation and may reduce or eliminate the accumulation problems; however, too much wind causes trouble from drifting snow and instrument vibration. The shelter should stand in the open well away from trees, buildings or other large objects. The principal temperature errors in these instrument shelters are due to radiation heating during a calm, sunny day when there is not enough air motion to ventilate the temperature sensors. This normally is not a serious problem during mountain winters. The shelter should be mounted with the access door facing north; this minimizes radiation errors from direct sunlight when the door is opened to inspect or service the instruments.

Maximum, minimum and present air temperatures are read from suitable thermometers mounted in the standard shelter described above. The dial-type max-min thermometer (A21 a & b) is less susceptible to breakage and easier to read and reset than the regular mercury and alcohol maximum and minimum thermometers (A21c), but the latter are more accurate. There is little difference in the cost. The dial thermometer should be mounted so that the sensor bulb underneath (or behind) is exposed to free air circulation and is away from the wall or floor of the shelter. It should not touch the thermograph or other instruments. The mercury and alcohol thermometers must be mounted in a standard Townsend support (B20) for proper use.

Figure 4. Study plot with weather instrument shelter adjustable in height to keep it the proper distance above the snow.

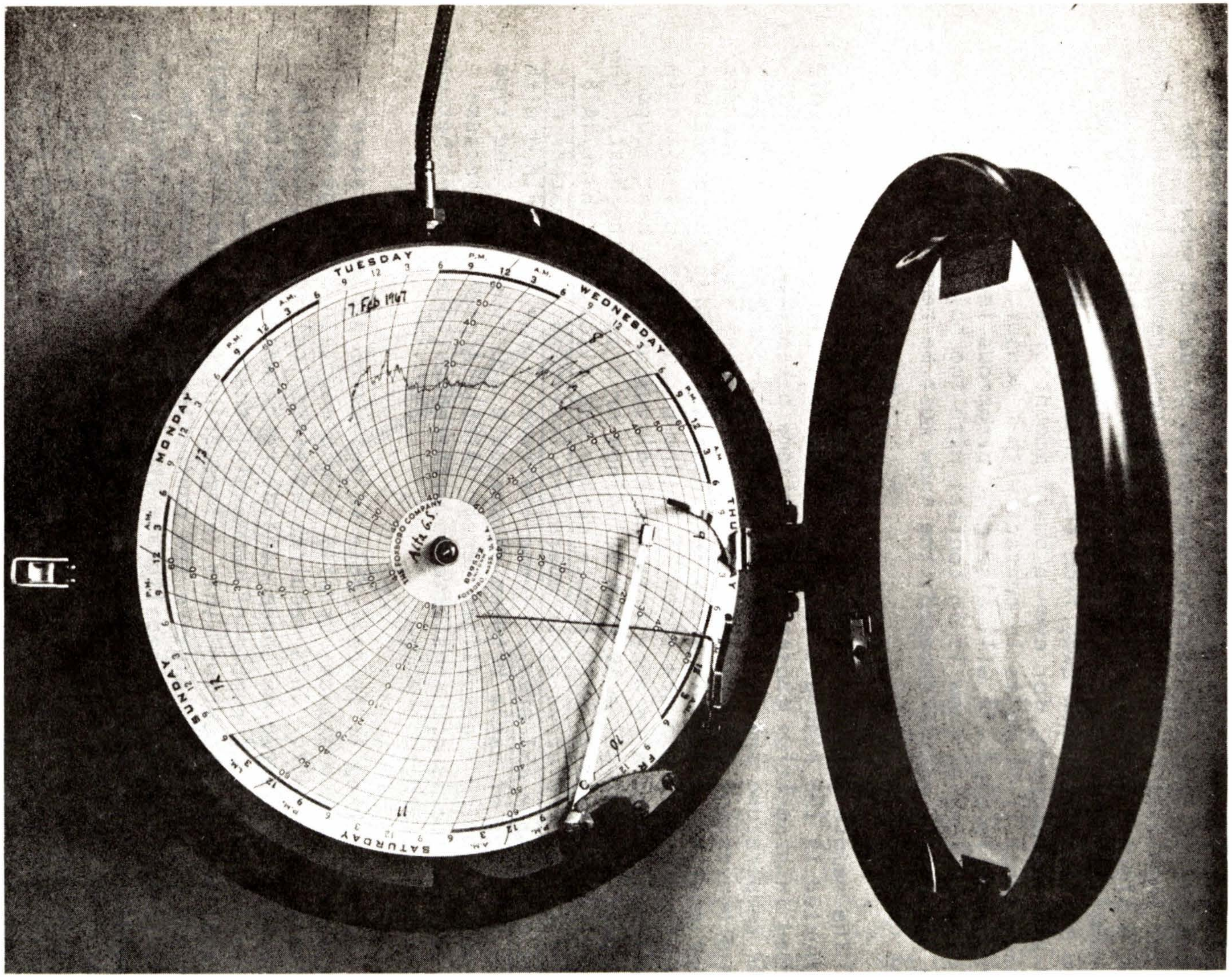

Figure 5. Remote-reading recording thermometer with disk-style chart. Range -40° to +60° F, with 1-week chart.

The standard instrument shelter readily becomes filled with snow during storms. The sensors will not indicate accurate air temperature as long as they are surrounded by packed snow. The shelter should be cleaned out and all the snow removed immediately after a storm. Note on the thermograph chart any periods when the instrument shelter was filled with snow. Special care should be taken to brush the snow away from the sensors of the dial thermometer and thermograph, for even a small amount of snow will cause a large error if it melts in contact with a sensor. If a hygrothermograph is used, it will also give erroneous indications of humidity as long as snow is in contact with the hair element. This element is easily damaged; the snow must be removed with great care.

The remote sensor (bulb) of a recording thermometer can also be mounted in the standard instrument shelter. It should be firmly clamped in a position chosen with the same precautions as for the other temperature sensors. If the shelter is located too distant from a convenient display point for the recorder, then the recorder sensor must be mounted in a separate shield. Details for construction of such a shield are shown in Figure 6. It must be located in a well-ventilated site away from local disturbances or heat sources. On top of a pole well away from buildings or trees is the best. <u>The recording thermometer with remote sensor and disc-style chart (A18 a & b) is the preferred air temperature instrument for weather stations at Class A ski areas.</u> These instruments may be obtained with up to 200 feet of cable between sensor bulb and recorder. The type of recorder using a gas-filled sensor (A18b) is preferred because the calibration is not sensitive to differences in elevation between sensor and recorder.

In some areas it is desirable to telemeter air temperature data over a long distance, usually from a mountain or ridge top to the valley floor. This requires an electrical sensor, usually a thermistor, and two or three conductors between sensor and the remote indicator. A number of commercial thermistor thermometers are available which perform this telemetering satisfactorily. (A31.) When the circuit resistance in the connecting cable exceeds a few ohms, it is necessary to recalibrate the indicator to give accurate temperature readings. Follow the manufacturer's calibration instructions. If the line resistance is large enough, it may not be possible to correct the calibration to fit the printed meter scale. In this case it will be necessary to construct a correction curve for use with the meter. Connect the thermistor probe to the indicator through a resistance equal to the anticipated line resistance (this preferably should be found by actual measurement of the installed line). Insert the probe in a temperature bath (a mixture of snow and anti-freeze in a vacuum bottle is useful over the normal range of sub-freezing temperatures) along with an accurate

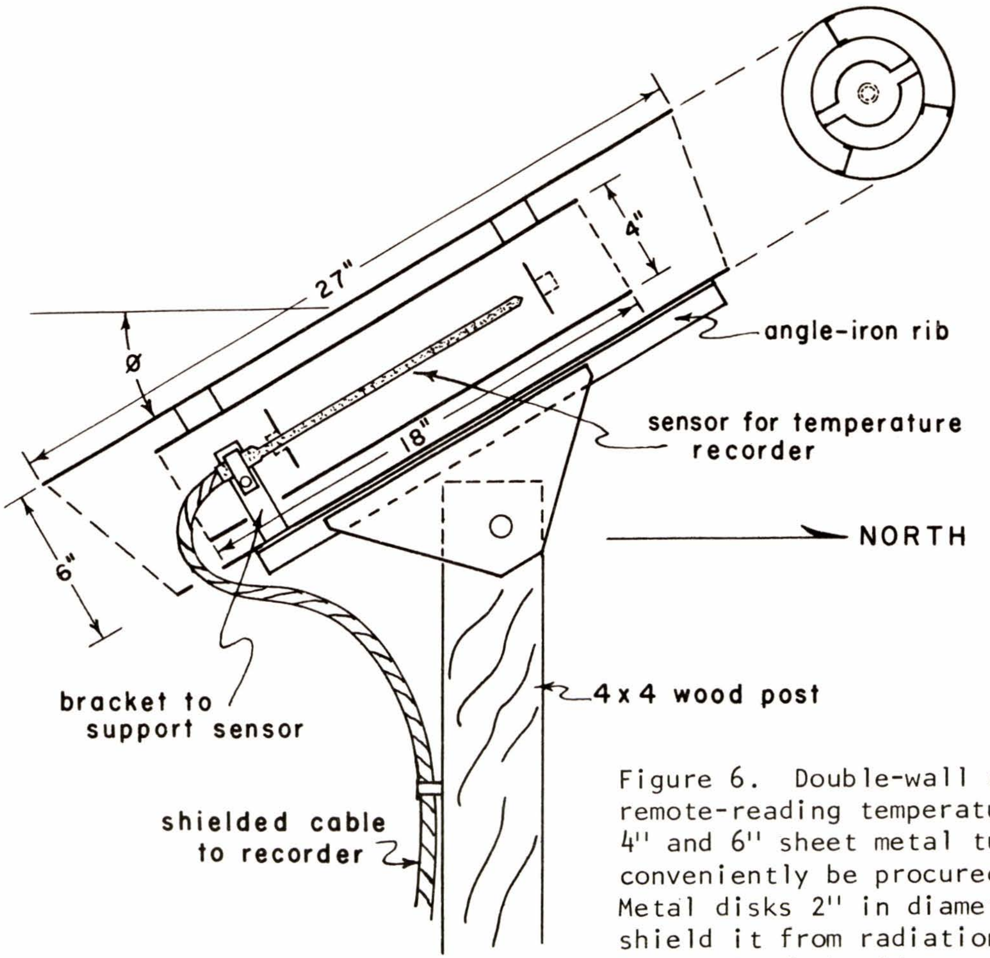

Figure 6. Double-wall radiation shield for sensor of remote-reading temperature recorder (A18 a & b). The 4'' and 6'' sheet metal tubes forming the walls can conveniently be procured as aluminum heating ducts. Metal disks 2'' in diameter at each end of sensor shield it from radiation entering ends of the tubes. The angle Ø should equal the latitude of the observation station. The 4x4 wood post should extend at least 6' above a roof or other obstructions. Exact details of assembly are not critical as long as sensor and tubes are concentric and dimensions are followed. Inside and outside surfaces, including that of sensor, should be painted gloss white.

thermometer. After temperature equilibrium is reached, note the thermometer reading and the temperature shown on the indicator. Repeat this procedure at a number of different temperatures over the normal operating range. From the differences between thermometer and indicator readings, construct a correction curve or table. This can also take the form of a revised meter scale pasted over the original scale.

The thermistor probe for temperature telemetry must be mounted with the same precautions used for other air temperature sensors. Mounting within a standard instrument shelter (A19) is acceptable. A smaller version of the shield shown in Figure 6 may also be used.

A thermistor thermometer with provision for multiple inputs may also be used to indicate snow, ground, or local air temperature from remote sensors. A portable version of this instrument is useful for measuring snow temperatures in the field (see below under Snow Pits).

Thermistors used in these instruments are carefully chosen and calibrated. Ordinarily they should maintain their calibration for long periods of time. But occasionally an unstable thermistor will be found which will not maintain calibration, or simply "goes bad". The only cure is replacement. There is some tendency for these difficulties to occur more frequently at high altitudes.

SECTION 3--SNOWFALL AND PRECIPITATION

Net snowfall is the depth of snow accumulated on the ground for any given interval. Precipitation is the amount of water reaching the earth's surface in a given interval, either in the solid form as snow or in the liquid form as rain.

There are no satisfactory and reliable instruments to measure snowfall automatically. Manual measurement and recording are required. A plate or board is placed on a level snow (ground) surface, the depth of snow accumulated on it measured with a ruler (A8a or A8b) inserted vertically, and the board is then reset at the surface. The board location must be marked by an adjacent stake. A painted piece of 1/4-inch plywood 24 inches square makes a satisfactory plate.

For convenience, the ruler or tape is usually replaced by a stake anchored to the middle of the plate. The snow surface level can then be conveniently read at any time. The stake must be stout and firmly anchored to the plate, for the assembly will suffer abuse when dug out of the snow, especially where snowfalls are deep and dense. Figure 7 gives construction details for a snow stake of proven sturdiness and durability. Lighter construction is not recommended; ordinary yardsticks or metersticks, for instance, are not strong enough. On the other hand, a stake which is too bulky will locally modify snow deposition and make accurate reading of the surface level difficult. A 2- by 2-inch stake is too large.

The total snow depth stake, however, may conveniently be a length of 2 x 2 lumber, for greater strength and stiffness are required. The total length should exceed the maximum expected snow depth. Every effort should be made to place this stake in the middle of a level area, otherwise the force of snow creep on even a very gentle slope will tend to tilt it. The stake should be straight-grain, clear fir, free of knots. Preferably it should be free-standing and supported only by the ground anchor. The accumulating snow cover will firmly support it during mid-winter, but in a windy location (to be avoided if at all possible), it may be necessary to guy the stake top when the snow cover is shallow. Guy wires should run horizontally to nearby trees, posts or poles. Do not guy the total snow stake with wires running diagonally from the stake top to anchors at ground level; snow settlement pressure will stretch or bend the guys, or pull and buckle the stake. Bottom of the stake should be clamped or bolted to a metal anchor firmly fixed in the ground, the nature of which must be chosen according to the character of the ground. A heavy angle-iron driven in 3 to 4 feet is satisfactory in soil.

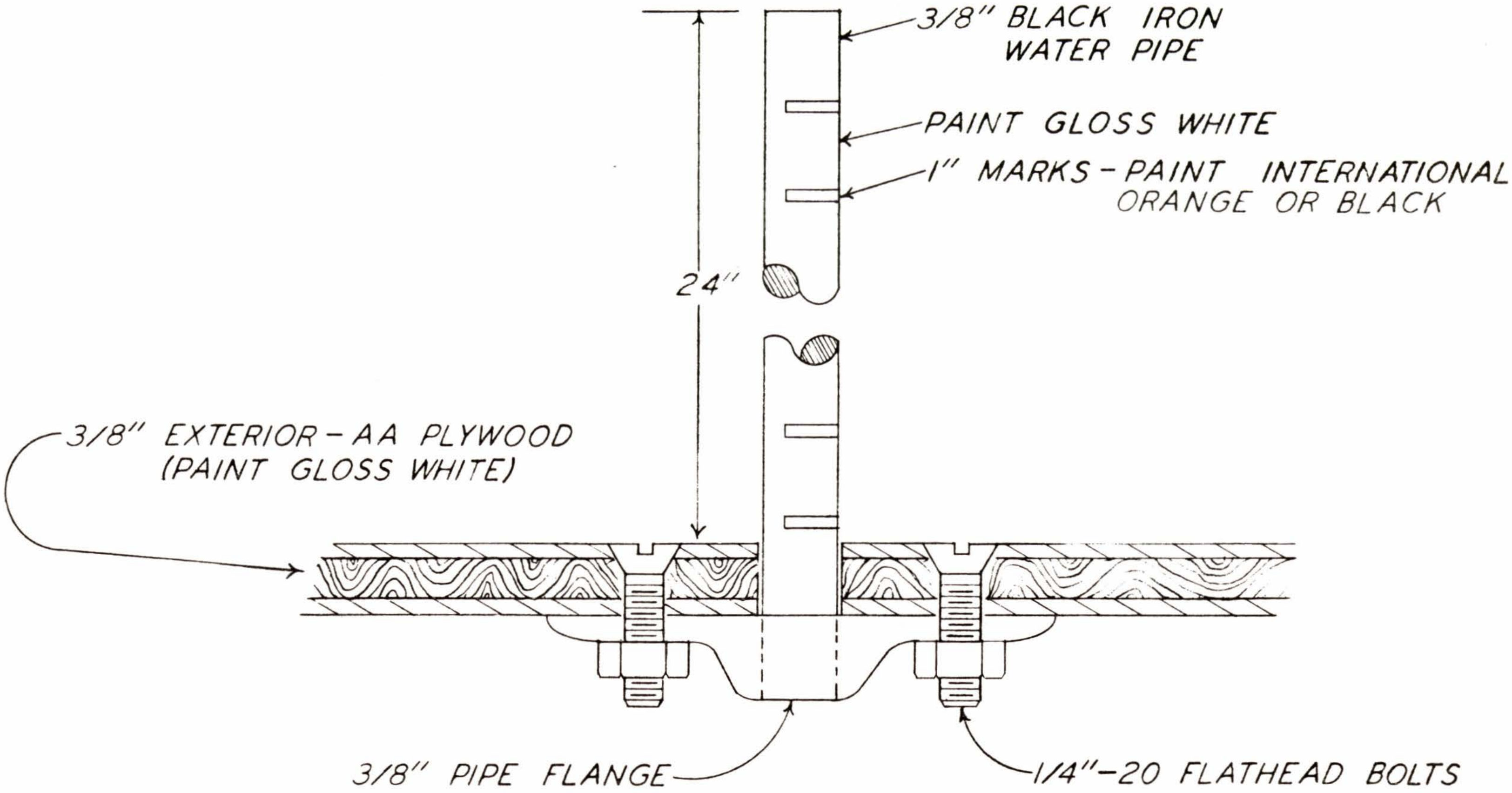

Figure 7. Construction details for platform-mounted snow stake. The 24-inch stake height may be varied to accommodate maximum expected 24-hour snowfall.

Both the platform stake and the total stake must be painted white to minimize heat absorption and consequent snow melt. A high-gloss paint is best, for snow and ice have much less tendency to freeze to this than to a matte surface. The recommended treatment is an undercoat of primer followed by two coats of white, high-gloss marine or equipment enamel. A metal primer should be used on the 3/8-inch pipe shown in Figure 7. It is important that this pipe be black iron; paint adheres poorly to galvanized pipe without a special primer. Paint black or bright-colored (International Orange is recommended) marks at 1-inch intervals on the stakes, numbered from the bottom up. All stakes should be numbered consecutively in inches and tens of inches, not in feet and inches.

Water content of each snowfall (precipitation) is measured by collecting a core of snow from the same snow board used for snowfall measurements. (See Figure 8.) This core is either weighed, or melted and the volume of water measured. The overflow can of the standard 8-inch rain gage (A20) is normally used to collect the core. An inexpensive substitute is an 8-inch diameter can constructed from sheet aluminum by any local sheet metal shop (A20). The lower tare weight of such a can is an advantage if the water content is determined by weighing. Galvanized steel cans (A20b) also offer more economy than the copper can of the standard rain gage.

Weigh the snow core collection can with a dial-type spring balance. A scale with a special dial reading directly in inches of water (B19) is available to government agencies through the U. S. Weather Bureau. A 6-kg autopsy scale (A33) has also proven satisfactory. For accurate readings, both scales must be suspended in a space free of wind and preferably close to room temperature. (The springs are not temperature-compensated.) To convert the net weight of snow in kilograms in an 8-inch can to inches of precipitation, multiply by 1.22. If water content is determined by volume, follow recommended melting procedure (see Weather Bureau Observing Handbook No. 2), pour the water into the rain gage (A20) collection can, and measure with the dipstick.

Precipitation is obtained manually from a standard 8-inch rain gage in case of rain. In climates where rainfall may occur at any time during the winter and affect avalanche conditions, the use of a rain gage is essential. To avoid problems with snow plugging the normal rain gage funnel, remove the funnel and the inner collection can. Expose the open, 8-inch outer can with a light charge of anti-freeze and a small amount of engine oil to melt the snow and prevent evaporation. The weight or volume of the anti-freeze and oil must be measured at the time of charging and deducted from later measurements to determine the amount of precipitation.

a. Inserting 8" can through snow to stake platform.

b. Inverting can and platform to recover snow core.

c. Weighing can with snow core to determine water content.

Figure 8. Use of 8" rain gage overflow can and spring balance to determine water content of 24-hour snowfall.

At present, not all Class A ski areas have a recording precipitation gage, but the aim is to equip most of these areas with such a gage. The recording precipitation gage (B14) is a self-contained unit with an 8" orifice, identical to that of the standard rain gage (A20a), a funnel, and a collection bucket which rests on a weighing mechanism. The weighing mechanism is connected to the pen of a recorder with a drum-mounted chart. For winter records of precipitation in the form of snow, the funnel is removed so the snow can fall directly through the orifice and into the bucket. Canopying or plugging of snow can constrict or block the orifice. This problem can be minimized where electric power is available by wrapping an electric heating cable (75-100 watts) around the lower part of the orifice just above the bucket. The exact arrangement of the heater and the amount of power required vary with temperature and snowfall intensity. It has to be adjusted by trial and error for each particular climate. No completely satisfactory solution has been found. Experiments with propane heaters have had only limited success with this type of gage. In the absence of electric power, the occasional plugging of the gage and loss or distortion of the precipitation record has to be accepted. Frequent attention and maintenance during heavy storms are essential in any case.

In normal operation this recording gage is used with a chart and drum that rotate once every 24 hours. Ideally a fresh chart should be installed each day, but it is permissible to leave a single chart in place for several days during dry periods or as long as the precipitation record remains clear. Preferably a fresh chart should be installed at the start of major precipitation periods.

The collection bucket is normally charged with one quart of permanent-type anti-freeze and two ounces of SAE 10 motor oil. The anti-freeze causes the snow to melt and the oil inhibits evaporation. After about 3" of precipitation (water equivalent) have accumulated in the bucket, it is dumped and recharged. The recharging can be kept a simple operation if 1-qt. cans of anti-freeze (and a can opener) are stored adjacent to the gage along with a container of oil.

Another type of recording precipitation gage is the heated tipping bucket gage (B15a and B15b). The 8" orifice of this gage is heated by electrical power, if available, or by propane. Snow is thus melted to water and is collected in a small metal bucket. When the volume of water in the bucket reaches .01", the bucket tips over closing an electrical contact. The gage is connected by cable to a remote event recorder. The "event" is the closing of the electrical contact that occurs with each tip of the bucket; hence, the recorder provides a continuous trace of precipitation in discreet .01" increments.

The principal problem with recording precipitation gages is securing a catch of snow in the orifice representative of what is falling on the ground. In a sheltered forest glade in a valley, where wind action is minimum, the catch is usually good, the only serious difficulty being caused by canopying at the orifice. As a general rule, good protection from wind is provided when the angle from the top of the gage to the top of surrounding trees or other obstructions is about 30 degrees. This angle should not exceed 45 degrees. Such shelter by trees will assure a representative catch in the gage.

Whenever the gage is exposed at a site where appreciable storm winds blow, it is necessary to provide a wind screen (A38) around the gage or a snow fence around the sampling site. The screen consists of a ring about 46" in diameter from which are suspended freely-swinging metal leaves. The gage should be mounted concentric with the ring and with the top of the orifice about 1/2" below the tops of the leaves. The screen still does not solve all the catch problems in high winds, but it helps.

The recording precipitation gage has to be mounted, together with its wind screen, in a location which will keep it above the snow surface even in the deepest snow years. Normally this will be on top of the instrumentation tower described below under Installation and Maintenance.

At locations where the snow study plot is more than 2000 feet below avalanche starting zones and is not representative of precipitation there, it becomes necessary to use a telemetered precipitation gage. A regulated power supply, potentiometric recording gage, and a single-channel analog recorder (A29a) are used in such situations. Total cost of this system is about $1000 plus cable. Details on instruments and circuitry for the remote precipitation gage are available on request from the Rocky Mountain Forest and Range Experiment Station in Ft. Collins, Colorado 80521.

The present state of technology in recording precipitation gages has not reached the point where these gages can be left alone and unattended during periods of heavy snowfall if an accurate precipitation record is needed. As better equipment is developed, or better means are devised for using present equipment, supplementary instructions will be issued.

SECTION 4--SNOWPITS

A good snow shovel is the one indispensable tool for the snow and avalanche observer. The best all-around model is the style known as a "Coal and Street-Cleaner's Shovel". This has a D-handle and a nearly flat, ribbed blade of square shape. It is available in both steel and aluminum (A5a). The aluminum model is preferred for back-packing to distant sites and is also highly recommended for avalanche caches. The steel is more durable and better-suited for digging in hard, icy snow. Other shovel types may be used for special purposes. A 14-inch grain scoop (preferably aluminum) is useful for deep, soft, new snow, but has too big a "bite" for comfortable shoveling of dense snow. A 12-inch grain scoop or coal scoop (not to be confused with the square shovel described above) also makes a useful, all-around snow shovel. A deeper dish than the street-cleaner's model makes it more efficient in soft, loose snow. A flat blade, on the other hand, does a much better job of trimming pit walls and cutting snow blocks. Avoid completely those shovels sold as "snow shovels". These are designed for pushing snow off sidewalks; they are totally unsuitable for serious digging. In climates where the snowpack is deep, dense, and hard, a useful auxiliary shovel is one with a slender, pointed blade on a short D-handle (Drain and post-hole spade, A5b). The blade should be only 5 to 6 inches wide at the shoulder. This is used to dig out density tubes after they have been placed in the pit wall. The type of shovel known on the West Coast as a "clam gun" also serves very well.

Density measurements are the backbone of pit studies. A set of density tubes is an essential part of snowpit equipment. The standard type has long been the 500 cc stainless steel tubes developed in Switzerland(A2). If carefully handled, they will give many years of service. Such tubes should be ordered with rubber or plastic caps which retain loose snow. These caps are necessary even if the tubes are carried only a few feet from pit wall to the weighing balance. A set of 10 tubes in a carrying case will meet most needs for snow density measurements. The tubes should be numbered with durable paint and the matching numbers painted on the caps of each tube. Tare weights can then be determined for each tube and its own caps. If the caps are switched from tube to tube, the combined tare weights will vary. If machine shop facilities are available, a considerable cost saving can be achieved by machining such 500 cc tubes out of stock stainless steel tubing (A2). Tubes made in this fashion according to the given specifications are very close in size to the Swiss standard tube and will accept the rubber caps made for the latter. Fiberglass tubes identical in size to the steel ones are also available from the supplier of the standard 500 cc tubes. These have a distinct advantage of lower weight, but are much less durable.

They perform satisfactorily in soft snow, but are not recommended for prolonged use in hard, dense snow.

For examination of pit profiles at avalanche fracture lines or at distant study plots, a portable snow density kit (A4) is convenient. (Figure 9.) This kit provides a single aluminum 500 cc sample tube, a suspension cradle, and a precision spring balance. Density profiles will be slower to obtain with a single tube, but this disadvantage may be worth the compactness and light weight of the kit when it has to be transported in a rucksack. The aluminum tube must be handled carefully to avoid damage to the cutting edge, especially in hard, icy snow. A steel tube cannot be substituted, for its tare weight will exceed the capacity of the balance, unless the snow sample is emptied into a plastic bag and weighed separately.

Standard density tubes normally are weighed with a triple-beam balance (A11a). This is a standard laboratory instrument of adequate accuracy which is reasonably sturdy for use in the field. Use of the 500-gram auxiliary weight may be necessary in dense snow ($\rho >$ 500 kg m^{-3}). A plywood case should be constructed for field transport of this instrument. The case also provides a convenient base for setting the balance on a snow surface. It is important to keep the spacing spring under the balance pan at all times except when the balance is set up on a firm base and in use. This spacer keeps the knife edges from contacting the agate bearings, which otherwise would be damaged during transport. A more compact spring platform balance is also available for weighing snow tubes (A11b).

A key instrument for pit observations and for determining snow structure without pit excavation is the ram penetrometer. It was introduced in Switzerland by R. Haefeli 30 years ago and has since become a standard instrument for testing snow strength and stratigraphy. Construction of various models differs in details, but the essential dimensions and mode of operation are identical for all. A firm in Chicago can supply ram penetrometers from stock (A1b). The ram penetrometer is also available from a mechanical fabricator in Zurich, Switzerland (A1a). The penetrometer furnished by the Chicago firm is built largely of stainless steel; the other has a body of aluminum. The manner of locking sections together is more convenient in the Swiss model, expecially for the mittened hand, but it is not entirely secure against unlocking while the penetrometer is deep in the snow. The stainless steel model has a more secure, though less convenient lock, but it tends to deform slightly at the joints after prolonged use in dense, hard snow.

Metallic dial thermometers with a long, slender stem are customary for snow temperature measurements in pit walls. None is available with an entirely satisfactory temperature range to give

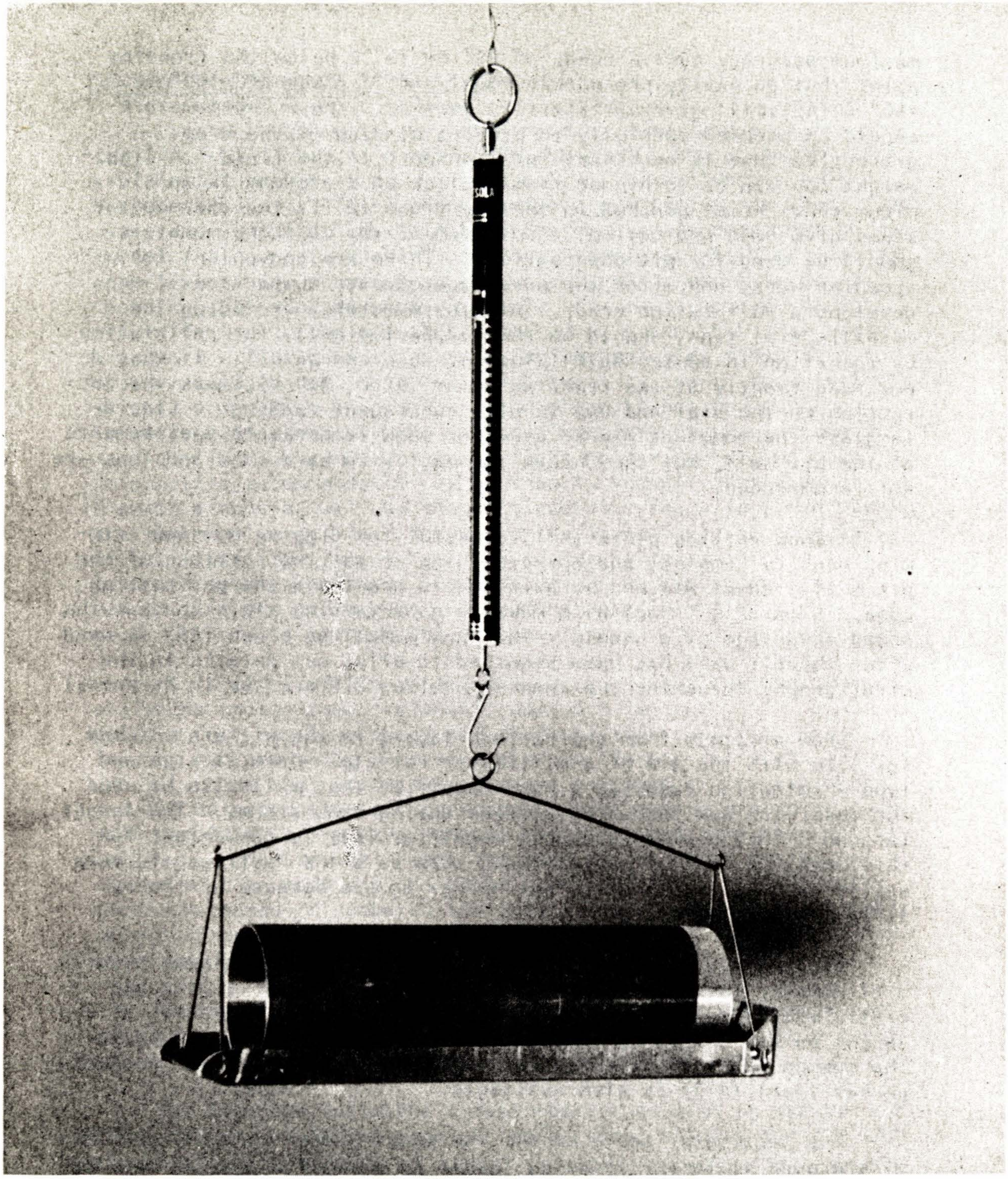

Figure 9. Portable snow density kit, using 500 cc sample tube made of aluminum and precision spring balance (A4). Total weight of kit is 220 grams (under 1/2 lb.).

maximum accuracy over a range of 20° or 30° C below the freezing point, but an easily procurable model with a range of -100° to +40° C (A3) will give satisfactory service. These thermometers should be handled carefully to prevent bending of the stem. A protective case is necessary for transport in the field. A lightweight one can be fashioned from a block of styrofoam in an aluminum can. Holes punched in the styrofoam to fit the thermometer stems give good protection. A minimum of two dial thermometers should be used for pit observations. Three are convenient for speedier work, and offer the advantage of easy comparison if one develops a calibration error. All thermometers, including the metallic dial type, should be checked periodically for calibration by insertion in an ice bath (slush of snow and water). If they do not read exactly at the freezing point (0° C, 32° F), mark the correction on the dial and use it with subsequent readings. Liquid-in-glass thermometers may be used for snow temperature measurements at the pit wall, but they break too easily in hard snow and thus are not recommended.

A snow cutting plate (A7) is useful for digging out and trimming density samples, and for smoothing or cutting sections of the pit wall. Bevel one end by grinding to provide a sharper cutting edge. A mason's trowel also makes a good cutting plate and has the added advantage of a handle. The snow modelling brush (A6) is used after the pit wall has been smoothed to bring out details in the stratigraphy (brushing the snow emphasizes differences in hardness).

Snow crystals from the various layers in the pit are checked for size with the aid of a millimeter reticle. Crystal size and type examination requires a hand magnifier that will also be used for observing new snow crystal type during snow storms. The larger (around 1 inch diameter) double magnifier (A9) is convenient for this work. A smaller pocket lens, such as a 10X Hastings, is more easily carried at all times but harder to use because of the restricted field of vision.

Pit observations or fracture line inspection on slopes require a clinometer to check slope angle. This instrument is also generally useful to the snow ranger for recording the steepness of avalanche paths, ski runs, and for rough-checking artillery targets. The common Abney level is satisfactory for most purposes. A compact pocket level (A12) is also available.

The centimeter scale on the ram penetrometer normally provides a reference scale for locating levels in a snowpit, but on many occasions a supplementary scale is required, for instance to measure fracture line heights or determine new snow depths in the field. A pocket tape (A8a) or folding rule (A8b) which can be easily carried is preferred. They should be graduated in both metric and English scales, for added convenience.

SECTION 5--AVALANCHE OBSERVATIONS

Little hardware is required to observe avalanches. The observer's sharp eye, an alert mind, and pencil and notebook (A35) are the main necessities. A good pair of binoculars is a very useful accessory. These are essential in a large area where size, type, and fracture line height of distance avalanches must be recorded. If a particularly good (and readily accessible) vantage point exists for scanning an extensive area, a variable-power spotting telescope may prove useful. It should have permanent provision for tripod or other fixed mount. Many ski area administrators will find frequent use for optical aids other than to observe avalanches. Check of closure signs, search for missing skiers, or routine inspection of snow conditions and cornice formation all profit by the use of binoculars or a telescope. Many quality instruments are available on the market; we make no specific recommendation other than to suggest that a 7- or 8-power binocular will be the most useful. The wide-field models are the most versatile. Because most viewing will be done in bright light, the large, heavy binoculars with large objective lenses are not necessary. Compact models easily carried by a man on skis are preferred. Government agencies often can find good instruments through GSA surplus lists.

It is difficult to record all the pertinent features on an avalanche unless some systematic approach is taken. In recent years a form has been developed to facilitate reporting avalanches and avalanche control action on Class A ski areas (Figure 10). The most important data are the name of the avalanche and the date and time of occurrence. Most active avalanche paths near populated areas have names. Use the local name whenever it is known. When several names are used for the same avalanche, a choice must be made and the other names avoided. Unnamed paths should be named or numbered for future reference. A photographic record of avalanche paths with appropriate names is the best way of assuring proper identification.

The date and time required refer to when the avalanche ran and not when the notes are made. If exact date and time are not known, an estimate must be made and recorded as such.

The standard avalanche classification as used in the United States covers avalanche type, trigger, size, sliding surface and air blast, in that order.

Avalanche type is designated as soft slab (SS), hard slab (HS), or loose (L). These abbreviations may be preceded by a D to indicate damp, or W to indicate wet snow conditions. Loose snow avalanches originate from a point and spread outward and

AREA Alta STA. NO. 200

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U.S. FOREST SERVICE

AVALANCHE CONTROL AND OCCURRENCE CHART

REVISED 10/71

OBSERVERS: Sandahl, Lev, Head

FOR KEYPUNCHING ONLY — COL 1 2 3 4 5 6 7

DAY OF MONTH (8-9)	TIME OF CONTROL OR OCCURRENCE (1) (10-13)	AVALANCHE PATH AND/OR TARGET NAME (14-32)	AVAL. PATH NUMBER (IF ASSIGNED) (33-35)	CONTROL MEASURES (2) (36-38)	TYPE HS SS WS L WL (39-40)	TRIGGER N, AS, AE, AA, AL, AO (41-42)	SIZE: 1-5 (43)	RUNNING SFC: O or G (44)	AIRBLAST = J (45)	TYPE OF MOTION (4) (46)	FRACTURE LINE (SLABS ONLY) DEPTH FT. (47-48)	LAYERS (5) (49)	% OF TOTAL AVAL. AREA THAT SLID (50-52)	LOCATION OF STARTING POINT (6) (53-54)	VERTICAL FALL DISTANCE FT. (55-58)	LOC. OF DEBRIS (7) (59)	IF AVALANCHE REACHED A ROAD: MAX. DEPTH ON CENTER LINE FT. (60-61)	LENGTH OF CENTER LINE COVERED FT. (62-65)	PEOPLE: CAUGHT (66-67)	BURIED (68-69)	INJURED (70-71)	KILLED (72-73)	VEHICLES: CAUGHT OR BURIED (74-75)	DAMAGED (76-77)	DAMAGE TO: BUILDINGS (78)	LIFTS (79)	MISC. (80)	REMARKS (Please use for clarifying statements about any entries. Note unusual or interesting events, give details on avalanche accidents, make dollar estimates on avalanche damage, etc. If necessary, use more than one line.)
1	2405	BALDY CHUTES	033		L	N	2																					small slide
1	0800	LOWER P RIDGE	038	29																								5 shots thrown, no action
4	0730	HI RUSTLER	029	32	SS	AA	2	O		S	1		20	TR	300	B												
4	0800	BALDY CHUTE	033	31	SS	AA	1				0		10		70													
6	0830	GREELEY BOWL	025	32	SS	AA	3	O		M	3		60	T	500													
		GUNSIGHT	024	31																								no action
		LOWER P RIDGE	038	221																								
		" " "	038	11	SS	AS	2				1	A	30	M	100				1									caught patrolman
10	2417	DEVILS CASTLE	021		SS	N	3								400													
15	0845	YELLOW TRAIL	050	22																								
		CHARTREUSE SLOT	042	22																								
		GLORY HOLE	054	24	SS	AE	3				3		50	T	150	C												
22	0800	UPPER P RIDGE	037	34	SS	AA	2								200													2 small slides
24	0700	SUPERIOR	009	32	SS	AA	4			M	4		90	T	2500	C	10	300					1					buried abandoned car on road; highway closed till 1030
25	2417	SUGARLOAF	056		L	N	2								150													3 small slides
30	1500	TANNERS FLAT	002		WS	N	4						90	T	3100	C	8	100										huge, slow-moving slide; barely missed 2 cars

(1) Use 24-hr clock — 0800, 0915, 1530, etc. When time is unknown, enter 2405 if event is suspected in A.M.; 2417 if suspected in P.M.

(2) Control Measures: Col. 36 - Type of control; 1 = Ski, 2 = H.E., 3 = 75mmR, 4 = 75mmH, 5 = 105mmR, 6 = 105mmH, 7 = Avalauncher 8 = other. Col. 37 - No. of shots or ski passes or lbs. of H.E. If greater than 9, enter 9. Col. 38 - If snow fractured w/o avalanche, enter 1; otherwise, blank.

(3) Examples: HS-AA-2-G = Hard slab, artificial artillery, small size, ran to ground; SS-AE-4-0-J = Soft slab, artificial hand charge, large size, ran on old snow sfc with airblast; L-N-1-0 = Loose snow, natural, ran less than 150 ft. slope distance, ran on old snow sfc.

(4) Type of motion: S = Sliding, F = Flowing or Tumbling, P = Airborne Powder, M = Mixed Air & Ground Motion

(5) If fracture line is confined to new (storm) snow layer, enter A; if fracture line penetrated and includes old layer, enter B; if uncertain, leave blank.

(6) Location of starting point: Col. 53 - T = Top, M = Middle, B = Bottom Col. 54 - L = Left, C = Center, R = Right

(7) Where avalanche stopped: A = Fracture Zone, B = Transition Zone, C = Foot of Runout Zone

(8) Enter no. of people caught, partially or wholly buried, injured, and/or killed; no. of vehicles partially or wholly buried and/or damaged; and no. of buildings, lifts or miscellaneous damaged. Explain misc. in Remarks column.

Figure 10. Example of standard Forest Service avalanche record chart, showing typical entries. An 80-column format is used to facilitate data reduction for computer use.

downward. Slab avalanches originate from a cliff-like fracture line. The distinction between soft and hard slab, however, is not well defined. The extremes are obvious, but guidelines are needed for the less obvious cases. If angular blocks of snow are found in the avalanche debris, the slide is usually called a hard slab avalanche, even though the blocks constitute a small percentage of the total debris. Where avalanche paths are long and steep the debris from even the hardest snow may contain no angular blocks. In this case, the density of the snow in the starting zone is the best guide. Snow densities of 250 to 300 kg/m^3 mark the transition from soft to hard slab.

Trigger action is divided into natural (N) and artificial (A). The latter is further divided into artillery (AA), avalauncher (AL), hand-placed explosives (AE), and ski (AS).

Avalanche size is generally ranked from 1 to 5 in ascending order. Following the European practice, size 1 is reserved for sluffs. These are snow slides that move less than 150 feet slope distance. Sizes 2 through 5 apply to small, medium, large, and very large avalanches for the avalanche path in question. This means that a medium (size 3) avalanche on a very large path may be bigger than a large or very large (size 4 or 5) avalanche on a smaller path. The best way out of this inconvenient situation is better data on the actual dimensions of avalanches.

The surface over which the avalanche runs is the fourth element of the standard avalanche classification. The sliding layer is usually either one of the layers within the snowpack (designated O) or the ground (G). Sometimes an avalanche starts out sliding over a snow layer then digs down to the ground. This is shown as OG in the classification.

Air blast is the final element of the standard classification. If this relatively rare event is observed, or if there is good evidence it took place, a J is entered. Air blast should be reported only if damage or severe turbulence is observed well ahead or to the side of the moving snow. Turbulence immediately ahead of the rapidly moving avalanche front is to be expected and should not be entered as air blast. Broken trees or other damage well to the side of the path or beyond the most distant avalanche debris is good evidence of air blast.

In addition to the standard avalanche classification, it is very helpful to have information on the type of motion, the size and location of the starting spots, the percentage of the total path that slid, the vertical distance traveled by the moving snow and notes on damage or injury caused by the moving snow.

The location of the starting spots and the percentage of the path that slide are very important in pinpointing areas of potential trouble. There is a tendency to consider a slide path safe once it has avalanched, and this is often the case if the entire path slid. If, on the other hand, only part of the path avalanched, the remaining snow poses a serious threat that might be overlooked unless complete data are recorded. The height of the fracture line, vertical fall distance and the proportion of the total path that slid all contribute objectivity to avalanche size.

Figure 10 also has space for entering avalanche control action that produced no avalanches. These are facts often not recorded, but left to memory. Since well-executed control action that produces no avalanche is an indication of stability, these data are too important to be left to memory alone, even on small areas.

One of the essential items of information about slab avalanches is the fracture line height. For on-site investigations, this can be measured with the tape or folding rule already described under Section 4 (A8 a & b). When inspected from a distance, the fracture line height must be estimated. One aid to accurate estimation is a reticle scale in binoculars, which provide a direct measure of objects if their distance is known. In the case of an active ski area where large-scale contour maps are available (as they now are for several Class A areas), a table of distances from regular observation points can easily be prepared. Consult a local supplier of optical instruments for information about reticles. Surplus military binoculars sometimes come with built-in reticles graduated in mils*. A table can easily be constructed to give object size (fracture line height) in terms of distance and mils.

Another aid to estimating fracture lines is to mark an object of known size adjacent to the fracture zone which will remain visible all winter. Rock outcrops, lift towers, or other existing structures can be measured and a list of sizes compiled for ready reference. Even better is the installation of reference marks especially for measurement purposes. For instance, a pole with short cross-arms of known spacing (say 1 meter) may be installed adjacent to the fracture zone of an active avalanche path. Comparison through binoculars of a fracture line with the cross-arm spacing

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* An artillery mil is 1/6400 of a circle. An infantry mil is the angle subtended by 1 yard at 1000 yards distance. 100 artillery mils equal 98.2 infantry mils. Reticles come in both kinds.

will allow accurate estimates of the avalanche slab thickness. Prominent painted marks on existing structures can serve the same purpose.

A useful adjunct to estimating avalanche size is a table of distances compiled by measuring the width and length of the active avalanche paths, especially those which are clearly defined by terrain features. If a large-scale map is available, this can be done from the map. Otherwise it is more convenient--and sometimes more accurate--to tape distances on the ground in the summer. Selection of sites for these measurements, as well as for the fracture zone markers described above, presupposes some experience with avalanche behavior in a given area. In a new development, it may take a minimum of two or three years of experience to know where to mark or measure.

The accurate recording of avalanche size and shape is greatly facilitated by a set of good photographs of all the principal avalanche paths in an area. Ground photos taken from good vantage points or low-level oblique aerial photos can be used. They should be printed to at least 8"x10" size and mounted on stiff cardboard or matt board. The boards can be punched for filing in a large, 3-ring notebook. Principal avalanche paths should be clearly outlined and named on the photos. Current avalanche activity for each season, or even for each storm, can be entered on transparent acetate overlays with grease pencil, or on tracing paper overlays with marker pen. It is important to label each overlay clearly according to date and associated photo.

Ideally, each major area where systematic avalanche observations are to be conducted should establish a master file of avalanche path photos annotated to show details of typical avalanche activity, response to different storm winds, and typical control measures. This serves as a permanent record by which hard-earned experience can readily be transmitted from each snow ranger to his successor, and provides a basis for analyzing each season's reported avalanche occurrence. Areas contemplating preparing such an annotated master photo file should request as an example a copy of the "Alta Avalanche Control and Safety Plan" (November 1969) from the Supervisor, Wasatch National Forest, Federal Building, Salt Lake City, Utah 84111.

NOTES ON INSTALLATION AND MAINTENANCE

Instruction Manuals

Most of the more complex instruments are furnished with instruction manuals by the manufacturer. These manuals give details about installation, operation and maintenance. While it may seem to belabor the obvious to insist that these manuals be read and heeded, experience has too often taught that the instructions manuals are immediately discarded or lost following acquisition of an instrument, so that maintenance and operation thereafter proceed on an improvised basis. This problem becomes especially acute for equipment like a quality recorder whose operational life may reasonably be expected to run for 20 years or more. Changing personnel, shifting files and modified installations sooner or later lead to an observer confronted with an instrument about which he knows nothing and for which the manuals have vanished. When this happens, the remedy is to write the manufacturer and request another manual for the instrument in question, furnishing serial number and date of purchase if known. But a properly organized observation station will not lose the manuals in the first place.

When a new instrument is received, immediately copy the instruction manual by Xerox or similar process, or else write the manufacturer for a second copy. File the original manual in a safe, permanent file where it will survive periodic discards or campaigns to "clean out the paperwork". Attach the copy to the instrument, or place it in the nearest convenient file where it is accessible to the observer using the instrument. When this copy vanishes, as it eventually will, make another copy from the carefully preserved original.

Instruction manuals contain the benefit of the manufacturer's hard-earned experience with his product. Much grief can be saved by following the instructions meticulously. Use only the specified types of accessories, such as charts, inks and lubricants. In a few instances this present Snow Safety Guide suggests procedures which may differ from the instruction manuals, but these are necessary modifications to conform to unusually rigorous environments. Otherwise, follow the manuals.

Whenever special installations have been made or standard instruments modified for some reason, these changes should be noted in the instruction manual. Any special instruments which are built instead of purchased should have their own instruction manual prepared by the builder. Wiring diagrams for wind systems or temperature telemeters should be drawn up at time of installation and prominently filed where they can later be found.

Carefully drawn circuit diagrams, showing accurately the wiring color codes and terminal strip numbers, will save an immense amount of labor when a new technician is called in to service the equipment.

A maintenance log should be kept for each instrument, showing the designated maintenance intervals and what is to be done, and logging the maintenance as it is performed. Careful, systematic maintenance will go a long way toward insuring reliable and accurate operation. Maintenance according to a regular, logged schedule is especially important for the type of seasonal observation which is done for avalanche purposes. Personnel often are on the job only during the winter months. There is a very strong tendency to drop everything in spring and not worry about maintenance until the first snow flies in the fall. By then there may not be time to do the job right, or a change in personnel will leave a complete maintenance gap unless an accurate log is being kept.

Observation Site and Instrument Tower

The snow and weather observations to be used for avalanche hazard forecasting ideally should be made at a common site which meets the following criteria:

1) Sheltered from strong winds

2) On a level surface

3) Easily accessible at any time of day or night

4) Representative of snow and weather conditions at avalanche release zones

All four of these criteria are seldom met by any one observation site. The most frequently neglected one is the fourth, because sites which satisfy this latter criterion seldom satisfy the other three. Accessibility is probably the single most important requirement, for even the most industrious observer will seldom maintain an accurate record if he has to travel a long distance to get the readings. It should be possible for the observer to reach the site in a few minutes at any time during day or night, without exposure to avalanche danger.

The level surface is necessary to get decent snow depth readings free of errors from snow drift and creep pressures on the stakes. A slight departure from level is acceptable providing a

uniform, plane area is available with dimensions at least twice the expected maximum snow depth. Ideally the snow stake area should be in the middle of a level plot with dimensions at least ten times the maximum snow depth, but practical constraints often will limit it to a smaller area.

A snow stake area exposed to strong wind action must be avoided as much as possible. Either wind scour or the deposition of drifts can lead to highly erroneous measures of the actual snowfall and representative mean snow depth for an area. A sheltered glade in a heavy stand of timber is the best stake site, but is not likely to be found at areas located near or above timberline. Examination of terrain and prevailing storm wind directions will often suggest likely sites. The best site cannot always be determined in advance when an observation station is set up in a new area. A year or two of experience with the behavior of natural snowdrifts will often lead to relocation of the stakes at a better site. Even on a windswept, open mountainside there will usually be small pockets sheltered from the wind which permit reliable snow observations, but these can often be identified only by day to day observation during winter storms. Even within what appears to be a sheltered plot there will sometimes be local areas of drifting and others relatively drift-free. These, too, may be identifiable only after a year or two of observational experience.

Almost all observation sites involve some sort of compromises with the four primary criteria. The advice of an experienced snow observer can help to achieve the optimum compromise and should be sought whenever possible. If, as is usually the case, a site accurately reflecting snow conditions at the avalanche fracture zone is the hardest criterion to meet, it will be useful to supplement the main observation site with additional snow stakes located higher on the mountain.

The normal observation site is customarily equipped with an instrument tower. This structure supports the recording precipitation gage above the maximum expected level of the snow cover and can at the same time provide a support along which the weather instrument shelter (A19) can be raised and lowered to keep it the proper distance above the snow surface. It is also a convenient place for storing above snow level such accessories as shovels, spare snow stakes, precipitation weighing scale, 8" precipitation gage can, or any special instruments which may be installed. The tower should be located in one corner of the observation plot where it will not interfere with snow deposition around the snow stakes. The elevation angle from top of the tower to the nearest obstruction, such as a tree, should ideally be about 30 degrees and should not exceed 45 degrees to assure proper exposure of the precipitation gage.

The method of tower construction, and its height, depends on the maximum expected snow depth. The tower should preferably rise at least four or five feet above the deepest snow cover. It must be sturdy enough to withstand normal winter storm conditions and especially to survive the effects of snow settlement and of creep if the observation site is not perfectly level. In the most extreme case of very deep, heavy winter snow cover in a coastal climate, where maximum depths can run to 25-30 feet, the precipitation gage has been mounted on a tall pole with a ladder up the side for access. (Figure 11.) In less extreme conditions a tower is customary, but it must be so constructed that there are no diagonal guy wires and no cross-braces below the maximum snow level. These are susceptible to settlement pressure and eventually will be damaged. Only vertical members of the tower should penetrate through the snow cover. This means that these members must be stiff enough and sufficiently well anchored to provide the principal rigidity of the tower without external bracing except at the top. Four telephone poles, properly creosoted and anchored in the ground, can form the basis for a suitable tower. A metal tower welded of six-inch steel pipe, like the one in Figure 12, has also proven suitable. The deck of this latter tower consists of steel landing mat, which can often be obtained from surplus sources. The exact details of construction are not critical, as long as the principles of good rigidity without any cross braces exposed to the snow are adhered to. The deck ought to measure at least six feet square. A solid hand rail is essential for safety.

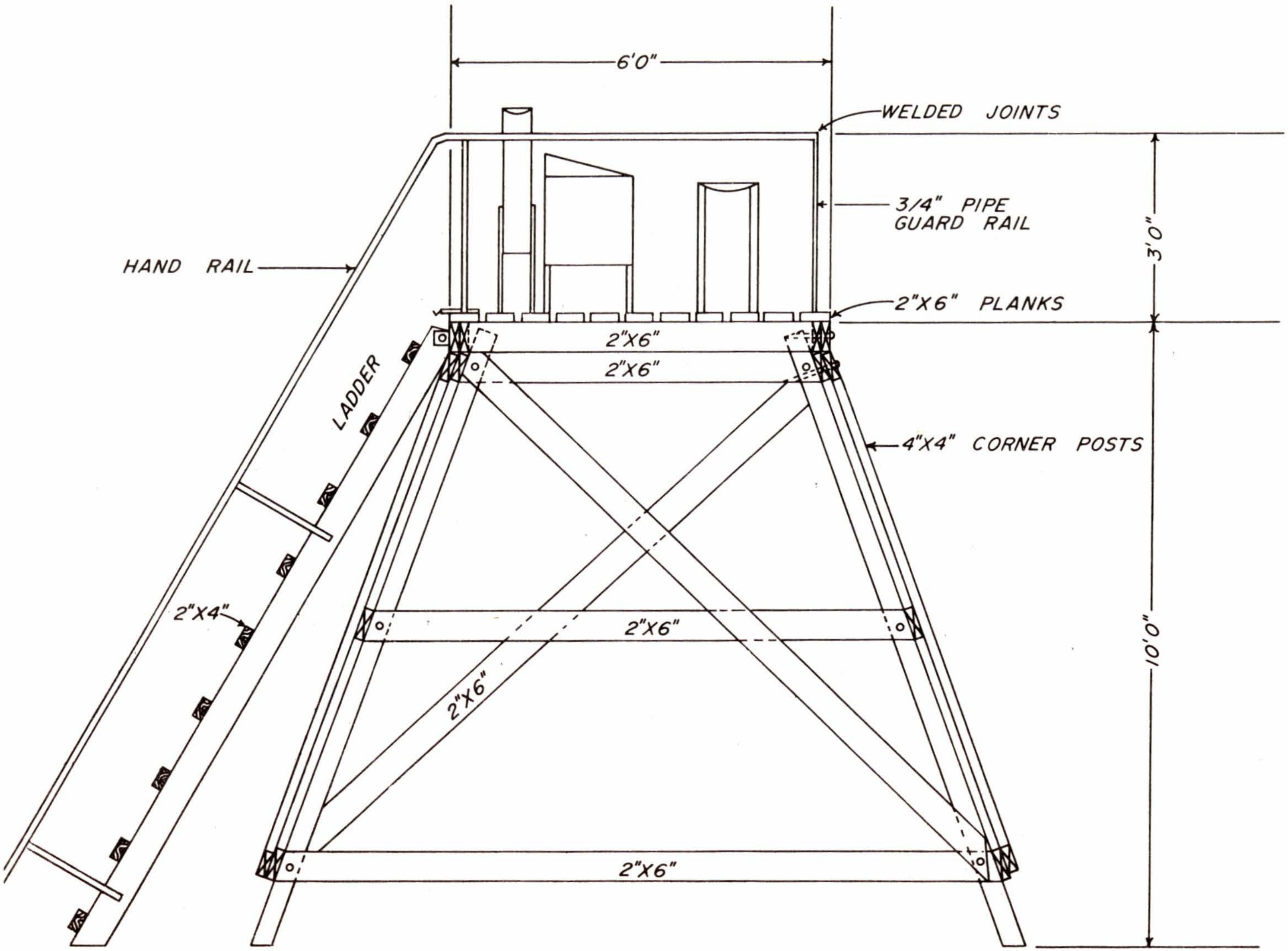
In continental climates with relatively shallow snow cover, a cross-braced wooden tower is acceptable, for there is much less problem from settlement forces. Figure 13 shows details of such a tower which has been satisfactory for use in the Colorado Front Range. The sloping instead of vertical posts would not be acceptable in deep snow country, for they would be subjected to severe settlement loading. In locations such as this where there is not a wide range in snow depths during the winter, the weather instrument shelter can be fixed on top of the tower instead of in a position to be raised and lowered along the side.

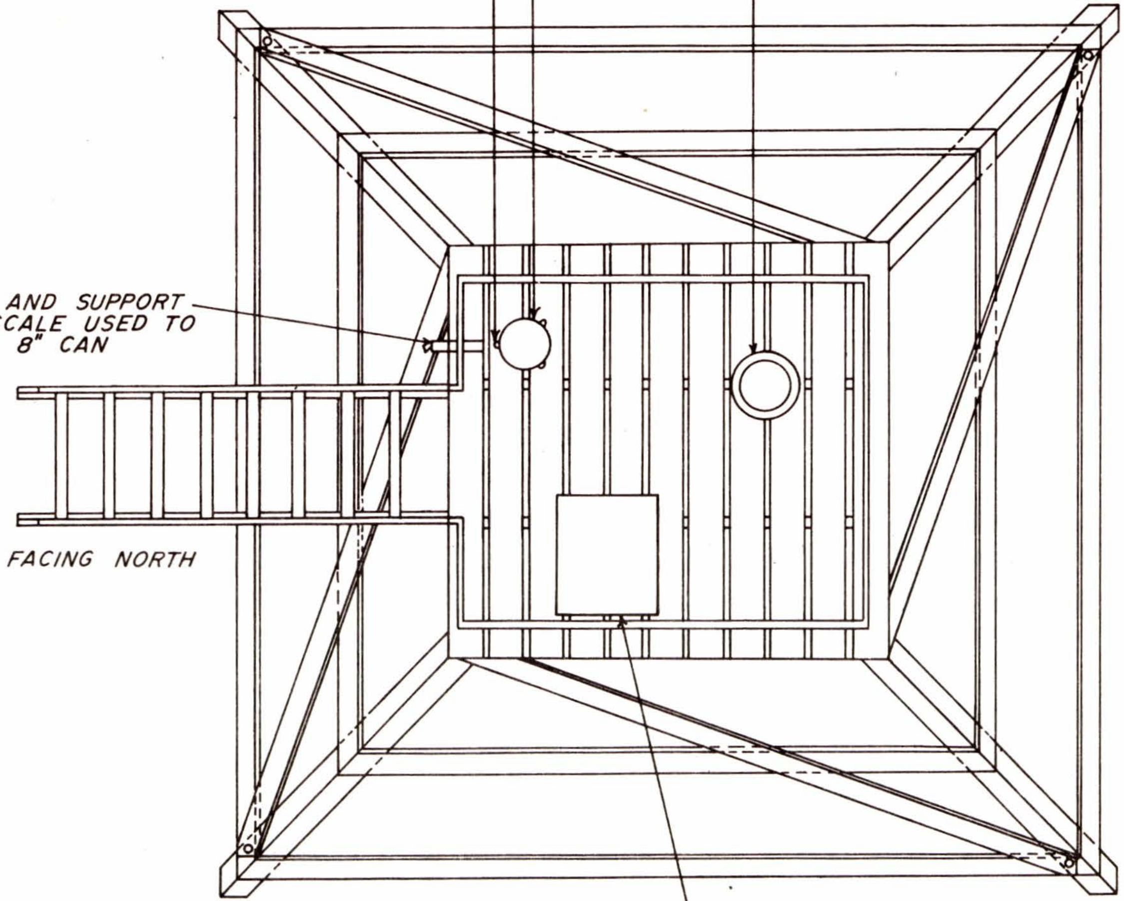
Regardless of the type of construction, instrument towers should be kept properly painted for preservation. Appropriate primer and finish paints should be used according to the material, wood or metal, making up the tower. If a weather instrument shelter is mounted on or alongside the tower, the tower should be painted white to minimize local heating from solar radiation. Otherwise a dark color is acceptable and in fact helps the tower to shed rime and snow when the sun comes out.

Figure 11. Example of a tower to support instrument shelter, precipitation gage and wind sensors in a maritime climate with a very deep snow cover. A cylindrical steel chairlift tower can serve as the basis for this type of construction. Ideally, the wind sensors should be mounted higher above the instrument shelter than seen here.

Figure 12. An instrumentation tower of welded steel pipe suitable for use in areas with a deep winter snow cover.

Figure 13. Construction details for an instrument tower suitable for use in a continental climate with shallow snow cover. In deep snow area, a tower like that in Figure 12 is preferred.




3/4" PIPE BRACING
8" CAN
FOR FUTURE RECORDING RAIN & SNOW GAUGE
HOOK AND SUPPORT FOR SCALE USED TO WEIGH 8" CAN
LADDER FACING NORTH
TEMPERATURE SHELTER
DOOR ON SHELTER OPENS TO NORTH
TEMPERATURE READ FROM LADDER

Anemometer Mast

Proper location and secure support for the anemometer and wind vane are essential for obtaining an accurate and reliable wind record. Assuming that a ridge crest or summit location has been selected which will give an accurate representation of prevailing winds affecting avalanche release zones, careful attention must be given to positioning the instrument tower in respect to local obstructions. Ideally the mast should be on a prominence which elevates it well above any local influences on wind flow. If large rock outcrops, trees, or other obstructions exist in the vicinity of the mast site, every effort should be made to keep the mast well away from them or else extend its height above the tops of the obstructions. If a single obstruction to wind flow exists, say a large tree, which cannot be entirely avoided, then the mast ought to be located so that it is downwind from the tree only for the least common wind direction. Placing the anemometer and vane downwind for prevailing storm winds from prominent obstructions should be avoided.

It may not always be possible to locate the anemometer and vane on a fully exposed promontory where they will measure the unimpeded flow of the wind. Locations on lower ridges or saddles may sometimes be necessary. Such sites will often experience modifications in both direction and velocity of the prevailing wind flow. Usually the degree of this modification can be determined only by measurements over a considerable length of time. Passes or saddles on a ridge are particularly poor sites because they tend to funnel the wind. If one of these less favorable sites must be chosen, caution will have to be used in interpreting the wind data until some experience has been built up about its relation to the actual prevailing wind. From the standpoint of the avalanche forecaster working in a given area, such qualified wind data may still be very useful, once experience has been built up in interpreting it. Wind data from such sites, though, are much less useful in analyzing the relationship of wind to avalanche formation in the larger view.

The recommended anemometer mast (A37, see also Appendix C) should be guyed at center and top. Some types of available TV towers are self-supporting (no guys) even in 100 mph wind if properly anchored in a good base. But these are not designed for such use when they are heavily loaded with rime; even a self-supporting tower should be guyed when it is installed on a mountain top. The guy wires should be 3/16" stranded steel cable, with properly fitting clamps, thimbles and turnbuckles. The guy wires themselves may have to withstand high wind pressures when they are thickly coated with rime, so there should be no compromise with strength. The anchor points of the guy wires should not be located where they

will be deeply buried under winter snow. If this occurs, the settlement pressure will add a large amount of extra strain which can damage or even break the mast.

Electrical Cables

The extensive installation of electrical cables usually comes about as part of a wind telemetry system, but shorter cables may often be used for signal and power circuits between an observation area and office or guard station. We cannot place too strong an emphasis on the importance of electrical systems using quality materials installed according to professional standards. Many years of observation and experience have made very clear the folly of short-cuts, cheap materials and amateur installations. They invariably break down just when they are most needed, and the cost of labor for trouble-shooting and repairs soon exceeds the original savings gained by doing the job "on the cheap".

It is worth noting that the difference between "amateur" and "professional" electrical work is not always congruent with the formal identification of these categories. Non-professionals with a real interest in electrical circuits and electronics sometimes do an impeccable job of wiring, while we have seen telephone linemen who didn't have the foggiest idea of how to install cables in a mountain environment. Good work is where you find it. The secret to success is careful, conscientious attention to good workmanship. The fundamentals of how to achieve this are taught in any trade school; actually executing it depends on an attitude of mind.

The preferred method of installing cables in mountain environments is by underground burial. Overhead lines are sometimes used, but they usually require more maintenance and a higher-than-average number of poles if the lines are exposed to icing and high winds. Underground cables are especially preferred if a large number of circuits are involved. The underground cable does have the disadvantage that defects are much harder to locate when they do occur. Therefore the use of only best-quality cables is mandatory if they go underground. Trouble-shooting can be simplified if splices are not buried; they should be brought to the surface and connections made at terminal strips in weather-proof junction boxes.

Assuming a good cable is properly installed (buried at least 6" below the ground surface), the two most likely sources of trouble are bulldozers and rodents. The bulldozer problem cannot always be eliminated in a developing ski area, but it can be minimized if the cable line is carefully selected in the first place, clearly marked, and then patrolled during periods of earth-moving

activity. The rodent problem can be controlled by using metal-sheathed cable, which is also an advantage for electrical shielding. Marmots in particular have a voracious appetite for electrical insulation. For this reason no cable should be exposed above ground--it must be run through metal conduit and into metal junction boxes. For a standard analog wind installation, the recommended cable is three-pair, 19 gage, direct-burial cable with 10 mil copper sheath (cost around 20¢ per foot). This can be ordered from local electrical supply houses.

Electrical cables should never be placed on the surface of the ground, for snow creep and glide invariably will break them. If it is necessary to run buried cables over exposed outcrops of bedrock, they must be placed inside heavy metal conduit and the conduit securely fastened with expansion bolts or cement grout to the rock. In zones of the large snow creep pressures, the greater strength of regular water pipe instead of conduit may be preferred. Joints in pipe or conduit should be securely fastened with proper couplings.

Federal agencies often will be able to acquire high-quality cable through Federal surplus lists. Any cable so acquired should be checked carefully to be sure it in fact meets the requirements for direct burial usage and will provide the required reliable service. Expert advice should be sought in evaluating such cable before acquisition is made, and then the cable should be checked on receipt to ascertain whether it is the same cable specified in the surplus-property order. Many such "free" cables are not suitable for the exacting requirements of a reliable mountain installation and are no economy in the long run. <u>Never</u> use surplus Army field phone wire or cable for these installations. This kind of wire is admirable for the purpose intended, namely one-time use in combat, but is not designed for long life as direct-burial cable. This advice is based on much hard experience.

All cables should be properly terminated in junction boxes. If the termination is exposed to the weather, the junction boxes should be weatherproof. There are so many different kinds of junction boxes available, and so many different requirements, that we will make no specific recommendations here. Consult a reliable electrical supplies dealer for recommendations for specific installations. It is not enough to bring a cable into a junction box and terminate it in a rat's nest of taped splices. The cable should connect to a terminal board, one wire to a terminal. The type of terminal called "barrier terminal strip" is recommended. See Figure 14 for an example of a properly installed junction box with terminals.

A typical wind telemetry installation will have a buried cable terminated at the upper end by a junction box mounted on

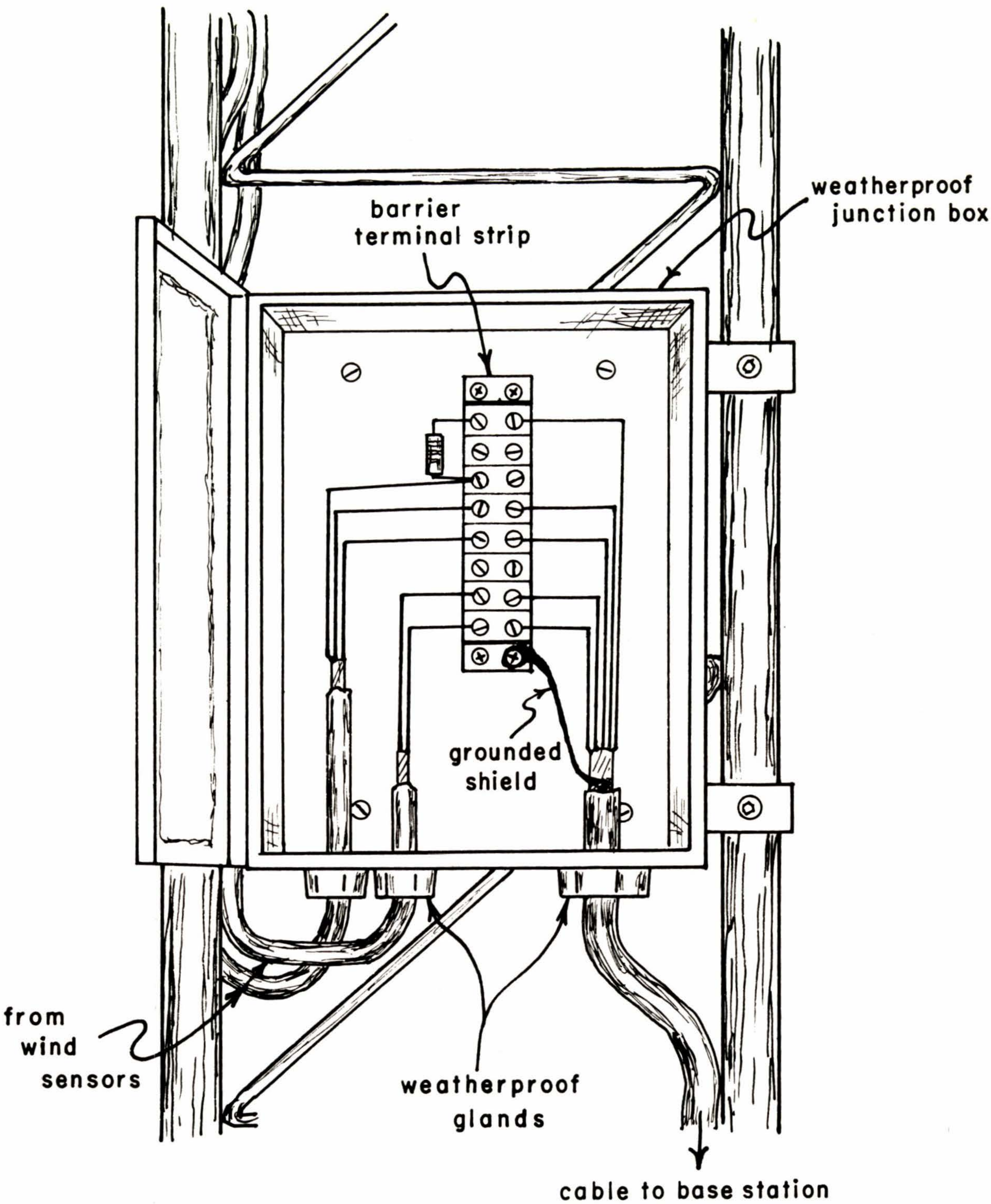


Figure 14. Example of a properly installed junction box at the base of an anemometer tower.

the anemometer mast. The lower end will terminate in a junction box adjacent to the recorder inside an appropriate office space. Any splices along the cable will be brought above ground and made on a terminal board inside a securely supported junction box. If possible, it is useful to have these splice boxes above the maximum expected snow depth. If not, their position should be marked for easy location when buried under snow. All cable exiting from the ground will be run through pipe or conduit into the junction boxes.

It is possible, though much more complicated and expensive, to use radio links instead of cables for wind system telemetry. Cables are much to be preferred because of their reliability. If peculiarities of terrain or distance make a buried cable impractical, radio transmission of wind data can be considered. A reliable system will cost from $10,000 on up. If such a system is contemplated, expert advice on its selection and installation should be sought. The Forest Service Electronics Center in Beltsville, Maryland 20705 (Telephone: (301) 474-4800) has made a study of radio telemetry systems suitable for this use and can advise National Forest users. Radio telemetry makes almost exclusive use of digital data transmission, therefore contact-type anemometers are much more compatible with such systems. It is possible to transmit analog data via radio links, but this involves considerable more complication and expense.

Rime

The accumulation of rime (freezing of supercooled cloud droplets onto solid objects) leads to serious calibration and maintenance problems with anemometers and wind vanes. Small amounts of rime quickly alter the response of the instruments to the wind, so that accurate data cannot be obtained. As the amount of rime increases, response of the instruments slows down until a point is reached where they cease to function. If large amounts of rime accumulate while high winds are blowing, serious damage may occur. Extra weight on rotating anemometer cups may damage the bearings; if too much weight accumulates, the cups can actually break off. The most serious damage occurs when only part of the adhering rime falls off the cups. The resulting unbalance can quickly destroy the anemometer if wind velocity is high.

Seriousness of the riming problem varies widely with climate. It is most severe where the supply of supercooled clouds is most abundant, namely in maritime climates. At some higher elevations along the Cascade or Sierra Nevada mountains riming is so frequent and heavy that it is extremely difficult to maintain anemometer

operation without complicated and special equipment. The degree of riming generally decreases with progress inland from the Pacific Coast, until the problem becomes much reduced--although never eliminated--in the continental climate of the Rocky Mountains. Typical storm and temperature patterns produce in many areas a characteristic "rime line", or altitude above which riming is much more common than it is below. Unfortunately this line often lies below the desirable site for an anemometer, but if it is possible to locate the anemometer at a satisfactory site in respect to the wind and still stay below the rime line, this will greatly diminish the problems from rime.

From time to time specially formulated coatings have been proposed for wind sensors which would inhibit or prevent adhesion of rime. So far, none has come to our attention which in fact will perform this function, including the frequently suggested teflon. In the absence of a heat source to eliminate the rime by melt, the best coating for anemometer or wind vane is still a coat of high-gloss black paint (see below under Paint). The black readily absorbs solar radiation, so the instrument surface is heated, the rime melts at the surface, and drops away. There is a definite advantage of a high-gloss surface over a dull or matte one. Black paint of course does not prevent rime formation at night or during storms with heavy overcast, but it does cause the instruments to shed the rime promptly as soon as the sun comes out.

The only sure way to eliminate the rime problem is to provide enough radiant heat directed at the wind sensors to keep the rime melted off as fast as it forms. This method, using electric infrared lamps, has been used successfully in Colorado to keep wind sensors free of rime even during rather intense periods of riming. Presumably this same method will work at other sites where heavy riming is more frequent, but it obviously is limited to mountain tops equipped with electric power. Earlier experiments with propane-fired radiant heaters in the Sierras were only partially successful. Whatever type of heater is used, it is safe to expect that a large amount of heat will be needed to keep anemometers rime-free in the more severe conditions of a maritime climate.

The tested heater system pictured in Figure 15 is recommended for anemometer installations wherever electric power is available and where riming is not severe. The three lamps are General Electric Type PAR 56 medium flood lamps, 120 volts, 300 watts. Each lamp is mounted in a General Electric Type S401 fixture with a Type S402 lens. These three fixtures are supported by pipe brackets at 120° intervals around a circle and 18" below the anemometer cups. The lamps are pointed upward so the radiant heat is directed at the anemometer cups. Exact details of the mounting brackets are

must be sturdy enough to withstand high winds and must not interfere with flow of air around the anemometer cups. Details of construction are obvious from Figure 15.

Where riming is a frequent cause of anemometer damage and no electric power is available, it may be necessary to resort to a different and more rugged anemometer. There is one model of contact-type anemometer (A24b) which has proven capable of surviving extremely severe rime and high winds. Use of this sensor of course requires a digital rather than an analog wind system. Conversion of an existing analog system to a digital anemometer is possible. Contact the Alta Avalanche Study Center for details if this conversion becomes necessary.

Wind vanes appear to be much less susceptible to rime damage than anemometers. They simply freeze up and quit functioning until the rime is removed.

Lightning

Lightning is an ever-present danger to mountain instrument installations. It is more apt to be a problem in summer and fall than in winter, but even then it may sometimes damage equipment. The proper protection for operating equipment is thorough grounding of all tower, cable shields and instruments, plus installation of lightning arrestors at cable terminals. Sensitive instruments such as meters and recorders should be protected with fuses appropriate to the current-carrying capacity of the circuits involved. It is important that fuses installed for lightning protection should be at the actual meter or recorder terminals (in-line fuses). If such fuses are located inside junction boxes or electronic chassis, it is still possible for electrical surges to by-pass them and enter the sensitive equipment.

The best protection during non-operating periods in summer is to remove the sensors (anemometer, thermistors, etc.) from the field and store them. Cables should be disconnected at junction boxes and meters or recorders disconnected from their signal inputs. A few moments spent each spring disconnecting wires and each fall reconnecting them can save a large amount of trouble and expense. It takes just one lightning strike, or even a ground current surge, to ruin a lot of expensive equipment.

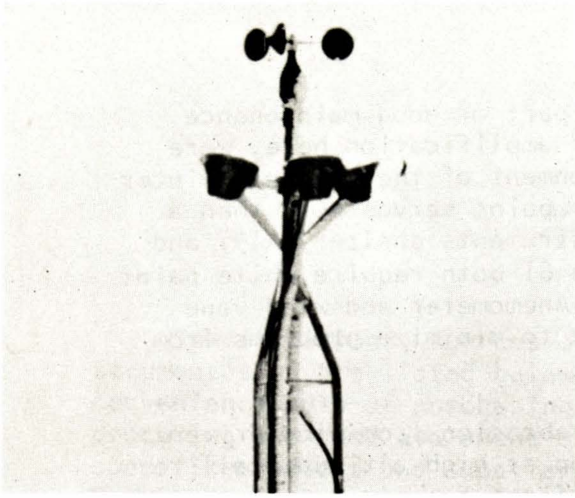
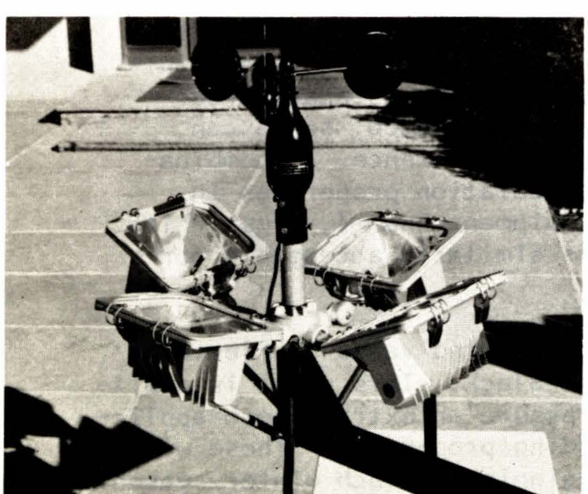


Figure 15. Above: A heat lamp assembly used to prevent rime from forming on an anemometer. See text for details.
Below: A heat lamp assembly for more severe riming conditions. See text for further details.



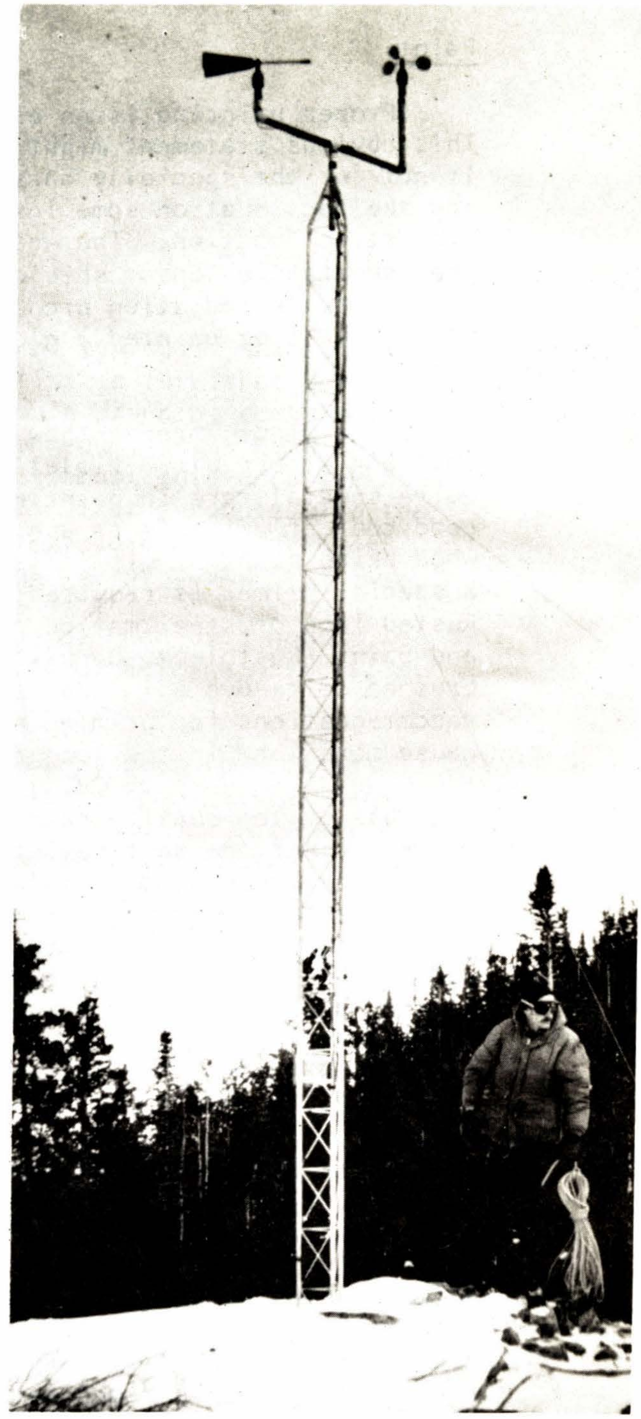


Figure 16. Typical anemometer and wind vane installation atop a guyed TV antenna tower. The mounting pipes are not furnished with the tower and must be custom fabricated.

Paint

Proper painting is an essential part of good maintenance. This obvious statement might not need amplification here, were it not for the specially harsh environment of the mountain winter and the fact that on some instruments paint serves more than a protective function. The weather instruments shelter (A19) and the temperature sensor shield (Figure 6) both require white paint with suitable radiation properties. Anemometer and wind vane need to be kept painted a gloss black to minimize problems from rime.

High winds, freeze-thaw cycles, abrasion from wind-driven snow and strong ultra-violet radiation at high altitudes all require special care in painting. The first step in applying a good coat of paint is to use the proper primer for the metal or wood being painted. If it is necessary to paint galvanized metal, a special primer is required, otherwise the paint will not adhere. Rusted iron or steel may be painted with a rust-inhibiting primer and paint (Rustoleum, Derusto) if it is first scraped and wire-brushed to remove all loose scale. Follow the paint manufacturer's recommendations for priming and avoid short-cuts, which usually cause more work in the long run.

Use of top quality paints is essential in the mountain environment. For the best resistance to weather on instruments and accessories, use Duco auto enamel, top-grade equipment enamel, or top-grade marine enamel. Federal agencies involved in the maintenance of high mountain instruments will need to be cautious about using paints furnished under General Services Administration contracts. Our experience with these has definitely been mixed. The small extra cost of purchasing fresh, top-grade paints from reputable manufacturers will yield many dividends in the long run. This is especially true for paint in pressurized spray cans.

White paints used on radiation shields need to have a high reflectivity in the visible parts of the spectrum combined with high emissivity in the infra-red. This combination assures minimum heating above ambient air temperature. No systematic radiation studies on suitable paints have been located, so we can only recommend on the basis of practical experience. A combination of good durability and favorable radiation properties in a brushing paint is found in Fuller Equipment Enamel, Gloss White. Krylon Acrylic Paint in Gloss White is similarly acceptable for paint in a pressurized spray can.

A suitable paint for anemometers and wind vanes is Flecto Varathane polyurethane enamel in Gloss Black. This paint is available in pressurized spray cans which assure an extra smooth application for maximum gloss and rime-shedding properties. These wind sensors should be repainted at the beginning of each winter season.

APPENDIX A

Specifications, sources and costs of typically suitable instrumentation are listed below. This list is furnished for the convenience only of purchasing officers in planning costs of and procuring snow and avalanche observation equipment. Mention of specific products and suppliers does not constitute endorsement by the U. S. Department of Agriculture. Other products with the same characteristics may be used as well. Government agencies will follow normal purchasing procedures in any case.

The letters "S.A." in parentheses, followed by a number, refer to catalog numbers in Catalog No. 8 of Science Associates, Box 230, Princeton, New Jersey, 08540.

The letters "FSN" followed by a number refer to Federal Stock Number. Weather instruments available from General Services Administration are catalogued under FSC Group 66, Part 1, Section A. Where known, the price to Federal agencies is given following the FSN number. See introduction to Appendix B regarding availability of meteorological instruments under U. S. Government contracts. Prices change, so get the latest quote from the company.

APPENDIX A

A1a. Ram penetrometer. A high-quality Ram penetrometer with 4 extension sections and 1- and 2-kg ram weights is available for \$70.97 plus \$31.56 shipping cost and import duty from Walter Buser, Kleinmechanishe Werkstatte, Karstlernstrasse 5, Zurich 43, Switzerland.

A1b. Ram penetrometer of different construction but identical performance, including one more extension section and canvas carrying case: Catalog No. F4050, \$360.00 from Test Lab Division, GEI Incorporated, P. O. Box 66310, Chicago, Illinois, 60666

A2. Standard 500 cc snow density tubes. Stainless Steel--\$9.00 each, rubber caps (2 required per tube)--\$0.75 each, from Test Lab Corporation (see above). Stainless steel tube stock for making density tubes--304WD Stainless Steel Tubing, 2 3/8'' OD, .049'' wall, price \$244.00 per 100 ft., order from local tubing distributor. Cut this tubing to 19.05 cm (7.50'') long and bevel one edge (cut and bevel on a lathe for best results). The Test Lab rubber caps will fit these tubes.

A3. Dial thermometer. Weston Model 226, -100° to +40°C., \$8.00 from Weston Elec. Inst. Corp., Newark, New Jersey (order through local distributor).

A4. Portable snow density kit. 500 cc aluminum sample tube, cradle, and precision spring balance--\$24.00 from Ernst Strohmeier, Kreuzstrasse 52, Rapperswill, St. Gallen, Switzerland. (See Figure 9.)

A5a. Snow Shovel. D-handle aluminum shovel with square blade. Wood Shovel & Tool Co., Picqua, Ohio, Model 4A Zephyrweight, \$7.95. (Order through local hardware distributor). D-handle steel shovel of same design: Ames No. 306, Coal and Street-cleaners Shovel, \$7.95. Also: True Temper CT2, \$6.16.

A5b. Drain and post-hole spade. Sears, Roebuck 9K 8308C, \$5.77.

A6. Snow Modeling Brush. For hard snow: Plastic whisk broom--procure from local dime store, under \$1.00. For soft snow: 3'' nylon paint brush--procure from local hardware supply, about \$1.50.

A7. Snow Cutting Plate. 6 x 12'' piece of .040'' 7075 alloy aluminum sheet. Procure from local metal supplier.

A8a. Metric Tape Measure. 2-meter steel pocket tape, graduated in meters, centimeters, and millimeters. Keuffel & Esser No. 860358, $4.30. Or: 3-meter, in inches and centimeters. Keuffel & Esser No. 7407.

A8b. Folding Ruler. 2 meters long, graduated in centimeters and inches, Keuffel & Esser No. 7966 ME, $2.35.

A9a. Hand Lens. Double pocket hand lens, 2X-4X-8X. Keuffel & Esser No. 830360, $1.85. Procure from local drafting supply store.

A9b. Hand Lens. Bausch and Lomb 10x Hastings triplet magnifier. $13.00. Order through local Bausch & Lomb distributor.

A10. Millimeter Reticle. E. R. Bogusch Measuring Slide--$0.35. General Biological Supply House, 8200 S. Hoyne Ave., Chicago, Ill. (Also distributed by the Douglas Stewart Co., Madison, Wisconsin 53704.)

A11a. Balance. Ohaus triple-beam balance model 750-S. $25.00 Order from local scientific supply house.

A11b. Dial-Type Spring Balance (Platform Scale). Chatillon Model F1261, with adjustable tare weight setting. Suitable for weighing snow density samples. $23.50. Phillips Scale Co., 3130 Elliott Ave., Seattle, Washington, or local Chatillon distributor.

A12. Clinometer. Suunto Fast-Accuracy Clinometer. $24.00 from Forestry Suppliers, Inc., Box 8397, Jackson, Mississippi.

A13. Sling Psychrometer. USWB Spec. 450.1016. (S.A. No. 208) $14.00. Spare thermometers, $4.00 each (they're essential).

A14. Psychrometric Tables. USWB. See Bibliography.

A15. Aspirated Psychrometer. Battery-driven portable psychrometer. (S.A. No. 206). $75.00. USWB Spec 450.8113.

A16. Thermograph. -35° to 110° F. 1-week clock. USWB Spec. 450.1201 (S.A. No. 151) $210.00 (FSN 6685-551-8331, $138.00).

A17. Compact Thermograph. (S. A. No. 156) $144.00

A18. Temperature Recorder. Disk-type, wall-mounted, with remote sensor.

(a) Weksler remote recording thermometer. Mercury-actuated, 12" diameter chart. -30^{o} to 120^{o} F., with 5 feet of tubing on sensor. (S.A. No. 168-12) $199.00. Additional length of sensor tube up to 250' at $1.60/ft. for first 100', $2.60/ft. for balance.

(b) Foxboro temperature recorder Model 12R-TA-3B. Gas-actuated, 12" diameter chart, 7-day clock, -40^{o} to 60^{o} F., circular wall-mounting case, with 5 feet of sensor tubing, $311.00. Additional length of sensor tube to 100', $0.75/ft.

A19. Instrument Shelter. Standard louvered shelter for weather instruments. USWB Spec. 450.0615 (S.A. No. 176). $130.00.

A20a. Rain Gage. Standard 8" rain gage with stand, funnel, collection can and overflow can, and dip stick. (S.A. No. 503) $75.00. 8" overflow can alone (for snow water content), $34.75. For snow water content alone, order 8" x 24" aluminum can with crimped seams from local sheet metal shop. $5.00 to $6.00. Seal seams with Dow-Corning Silastic or similar sealant.

A20b. Rain Gage. Standard 8" can in inexpensive galvanized sheet metal. $21.00. Rex Industries, 625 North 335 West, Salt Lake City, Utah 84100.

A21. Maximum-Minimum Thermometer.

(a) Mercury-actuated dial type, USWB Spec. 450.1214, -40^{o} to 120^{o} F. (S.A. No. 117) $57.00.

(b) Bi-metal element, dial type. (S.A. No. 115-1) $35.00.

(c) Max-min liquid-in-glass thermometers, with support (S.A. No. 111) $45.00.

A22. Microbarograph. Standard type. (S.A. No. 355) $375.00. (Weather Measure No. B211) $275.00. Specify altitude of observation site.

A23. Recording precipitation gage. Standard weighing type with clock-driven chart, USWB Spec. 450.2201 and 450.2203, 8". (See B14 and B15.)

A24a. Anemometer, Contact Type. Standard Weather Bureau 3-cup with totalizing dial and 1-mile contact. Belfort No.

5-349A (S.A. No. 404, $212.50) (FSN 6660-551-3196, $168.00). This model is susceptible to rime damage in adverse mountain conditions, but is now replacing the "old Weather Bureau model" (S.A. No. 403) which is rugged, but inaccurate at higher speeds.

A24b. Anemometer, Contact Type, Extra Durable. The only anemometer we have encountered with proven ability to survive 100+ mph winds under heavy riming conditions is the Model R/CCA 5" Cup Contact Anemometer manufactured by Rauchfuss Instruments & Staff Pty Ltd., 11 Florence St., Burwood, Victoria 3125, Australia. The rotating assembly is fabricated of stainless steel. It is available with choice of 1, 2, 4 or 6 contact closures per mile/hour or per knot of wind run. $150.00 FOB Burwood.

A25. Anemometer, Generating Type.

(a) Belfort windspeed detector, (AC generating type). (S.A. No. 417), $105.00 (Non-linear output below 10 mph).

(b) Windspeed transmitter (DC generating type). Output linear 0-4.0 volts DC from 0-100 mph. (S.A. No. 406) $179.00. Must be modified for recording. Model F 420-C windspeed transmitter made by Electric Windspeed Indicator Co., 12234 Triskett Road, Cleveland, Ohio 44111, $157.00 (See Appendix B).

A26. Wind Vane, Contact Type. Electric wind vane, contacts for eight direction. (S.A. No. 425) $27.50. (See Appendix B for heavy-duty model.)

A27. Wind Vane, Resistance Type. See Appendix B.

A28. Operations Recorder (Event Recorder).

(a) Esterline-Angus* Model A620X Operations Recorder with hand-wound spring chart drive. Portable, wall or switchboard cases available. 10-pen recorder, $515.00, uses chart 1710-C (3" per hour chart speed). 20-pen recorder uses chart 1720-C (3" per hour). Order from local distributor or Esterline-Angus Company, Inc. of Indianapolis, Indiana.

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*All Esterline-Angus products are available under Government contract. Government Agencies should order through their local E-A distributor and refer to current contract number.

(b) RustRak 4-channel event recorder (suitable for wind velocity only). 110 v AC clock drive, 24 v DC pen solenoids (Allied Electronics Co., 2400 W. Washington Blvd., Chicago, Ill. 60612. Cat. No. 908-0391), specify 3"/hr. chart speed, $136.50. 24 v DC power supply, Cat. No. 908-0432, $31.12.

A29. Analog Recorder.

(a) Single channel: Esterline-Angus Model A601C Recording Milliammeter, 0-1 ma range, hand-wound spring chart drive. Uses chart No. 4313C (3"/hr.).

(b) Dual channel: Esterline-Angus Model A602-C with No. 2 hand-wound spring chart drive, each channel 0-1 ma., $754.00 (portable case). Uses chart No. 31085ZB (1-1/2"/hr.). (See B4)

Consult manufacturer's representative for further ordering details of above recorders.

A30. Hygrothermograph. Vertical drum type. WSWB Spec 450.8202 (S.A. No. 255) $230.00. (FSN 6685-551-3188, $122.00).

A31. Temperature Telemeter. See equipment made by Yellow Springs Instrument Co. and distributed by scientific supply companies.

A32. Electromechanical Counter. Veeder-Root Form No. Q 150704, 4-digit resetting, 24 v DC, $16.00.

A33a. Dial-type Spring Scale. 6-kg. autopsy scale, 2 kg. per dial revolution, 10-gram graduations, Chatillon No. 806, $62.00. John Chatillon and Sons, 85 Cliff Street, New York, N. Y. (Distributors in principal cities)

A33b. Weather Bureau weighing scale. Detecto Mod. No. 0127-H-40, 2-revolution 40-lb capacity with decal to read in inches of water. Available to U. S. Government agencies through inter-agency purchase from NOAA. About $70.00.

A35. Transit Book No. 820020, Hardboard back; nylon coated, wire spiral binding, "Rite in rain" paper. Keuffel and Esser Co., 145 Yuma St., Denver, Colorado 80223, or other cities. 64 cents each.

A36. Low-Temperature Instrument Grease. Hamilton Type T-5211. $1.75 per ounce. Order direct from Hamilton Watch Company, Lancaster, Pennsylvania 17604.

A37. Anemometer Mast. TV antenna tower manufactured by Rohn Mfg. Co., Peoria, Illinois, distributed through electronic wholesale houses in principal cities. Normal anemometer installation (30 feet high) will use three 10-foot tower (extension) sections No. 25 G, two guying assemblies No. GA25G, accessory platform to fit on top of a normal section, two special weather instrument attachments, about 300 feet of 3/16 extra high strength guy cable, six turn buckles "eye and jaw type", 48 cable clamps, 24 wire rope thimbles, and four 1/2-inch bolts 8 inches long, eight hex nuts, and eight washers for 1/2-inch bolts. Order 40 pound-per-square-foot tower configuration. Various base plates are available, but a hinged base plate is recommended. Consult local distributor for details and current prices. (Complete tower will be between $150-$175.)

A38. Wind Screen for Precipitation Gage (B14). Improved Alter-type, USWB Spec No. 450.2151/A, Rev. 6/1/57. (S.A. 505-1) $104.00.

A39. Low-Ripple Battery Eliminator and Charger, Eico Model 1060W ($87.62), or low-voltage DC source of similar capacity. Consult local electronic suppliers.

A40. Recording Precipitation Gage. Heated tipping bucket type with remote event recorder. (See B15a and B15b.)

APPENDIX B

This Appendix consists of a list of recommended major instruments and their accessories for Class A avalanche areas on National Forest lands. It is arranged here for convenience of Federal purchasing agents. Information given here in many cases duplicates that in Appendix A. Costs are Federal Contract costs wherever applicable, and represent the latest available information as of January 1973. Some of these items are listed in GSA catalogs, FSC Group 66, Part 1, Section A. Others, also available on Federal Contract, are not so listed. Federal Contract numbers and designated suppliers change from year to year. Purchasing agents should contact the manufacturers' representatives and make purchases according to provisions of current contracts. We have found it impossible to compile a list of contractors and contract numbers which will remain up-to-date long enough to be useful to readers of Snow Safety Guide No. 2.

APPENDIX B

WINDSPEED AND DIRECTION

	Item	Source	Unit Cost
	ANALOG SYSTEM (Recommended Wind System)		(Federal Contract cost where applicable)
B1.	Windspeed transmitter Cat. No. F420-C, modified for recording. 4.0 volts D.C. at 100 mph and linear. With steel cup rotors.	Electric Speed Indicator Co.	$157.60
B2.	Wind direction transmitter No. F420C-2 modified for recording on twin-channel Esterline Angus A602C. Not on contract.	"	$165.00
B3.	Power supply and circuitry for recording vane, modified. Not on contract.	"	$125.00
B4.	Esterline Angus Model A602-C twin-channel recorder. Portable case with #2 handwound chart drive, hour and minute feed. Scale 0-100 each side. Current to each channel is 0 to 1.0 m.a. Two pen elements. Chart speed 1 1/2 inches/hour.	Local Esterline Angus Distributor	$754.00
B5.	12 Esterline charts No. 31085ZB, 1 1/2 inches per hour.	"	$ 24.60
B6.	Inkwells for A602C, Part No. 14616-2 red and green ink. (2 to a package)	"	$ 6.30
B7.	Accessory kit for E.A. Mod. A602C. Part No. 14617-2	"	$ 4.00

	Item	Source	Unit Cost
B7a.	Ink - 1 pint red, No. 61101-R 1 pint green, No. 61101-G	" "	\$ 4.00 \$ 4.00
B7b.	Anemometer tower. (See A37 and Appendix C)		\$200.00
B7c.	Triplett Model 310 Volt-ohm-milliammeter	Local electronic supplier	\$ 46.00

OR

	CONTACT SYSTEM (Alternate Wind System)		
B8.	Totalizing anemometer, 24 Volt D.C. Max. 0.5 amp. One mile and 1/60 mile contacts FSN 6660-551-3916	Henry J. Green Instrument Co.	\$169.00
B9.	Pintle for mounting anemometer Item No. 18-2. Part No. 2985	Belfort Instrument Company	\$ 17.50
B10.	Wind direction transmitter (less vane) with universal bearing. U. S. Weather Bureau Spec. No. 450.6112. 8 contacts. Max. 3 amp. at 25 volts D.C. With vane, add \$34.00. FSN 6660-551-8285	"	\$147.00
B11.	Electric Speed Indicator Spread tail vane - W.D.V.-400 - 1C. U. S. Weather Bureau Ser. No. S/N F012. Fits wind direction transmitter. Not on contract.	Electric Speed	\$ 24.00
B12.	Esterline Angus Model A602X Operations - 10 pen event recorder. Portable case with #2 hand wound chart drive. Common return with 6 or 12 volt D.C. (specify one). Chart speed - 3 inch/hour.	Local Esterline Angus Distributor	\$515.00

Item		Source	Unit Cost
B13.	24 charts No. 1710-C, 3 inches per hour.		$ 40.80
B13a.	Anemometer tower (See A37 and Appendix C)		$200.00
B13b.	Volt-ohm-milliammeter (See B7c)		$ 46.00

PRECIPITATION

B14.	Recording rain and snow gage Belfort Cat. No. 5-780 with 12-inch dual traverse. LESS CHART DRIVE AND CYLINDER BUT WITH (100) 192 hour charts No. 5-4046B, complete with pen, ink, and dash pot fluid. FSN 6660-558-0157	Belfort Instrument Company	$277.00
B15.	Model 301D Drum chart drive, battery actuated, 3.0 volts D.C. for recording rain and snow gage--drum height 6 5/8". With power pack. Gears for 192 HOUR CHART. Part No. 8171, Group 5. With power pack. (B14, B15, B15a and B15b are optional items. Consult Rocky Mountain Forest and Range Experiment Station before purchasing.)	Belfort Instrument Company	$ 82.00
B15a.	Model P511E heated remote recording snow gage. Electrically heated. Uses Model P521 Event Recorder. Not on contract	Weather Measure Corporation	$555.00
B15b.	Model P511P heated remote recording snow gage. Propane heated, no electrical power needed. Uses Model P521 Event Recorder. Not on contract	"	$645.00

	Item	Source	Unit Cost
B16.	Standard 8-inch can, 24 inches in length (for obtaining snow cores). Galvanized - no paint. Not on contract. F.O.B. Salt Lake City.	Rex Industries	\$ 21.00
B17.	Standard 8-inch can, 42 inches in length (to be used as a standard rain and snow gage.) Galvanized, painted a flat black. F.O.B. Salt Lake City. Not on contract.	"	\$ 24.00
B18.	Support for 8-inch can, with angle iron legs. Not on contract, F.O.B. Salt Lake City.	"	\$ 16.50
B19.	Weather Bureau weighing scale. Detecto mod. No. 0127-H-40, 2 revolution-40 pound capacity, circular dial with decal (reads directly in inches water) without cover glass or sash. Adjustable tare pointers. Interagency purchase.	NOAA, National Weather Service	\$ 70.00

TEMPERATURE

B20.	Townsend all metal thermometer support. Weksler Cat. No. 322A. FSN 6685-550-6739 (Also available from Henry J. Green Instrument Co. for \$22.00.)	Weksler Instrument Corporation	\$ 15.54
B21.	Maximum thermometer. H. J. Green Cat. No. 101. Range -38^{o} F to $+110^{o}$ F approx. 2 @ \$15.00 each. Replacement max. without backing available separately @ \$12.00 each.	Henry J. Green Instrument Company	\$ 30.00

	Item	Source	Unit Cost
B22.	Minimum thermometer. H. J. Green Cat. No. 108--amber colored alcohol. Range -50° F to +110° F approx. 2 @ $14.00 each Replacement min. without backing available separately @ $11.00 each.	"	$ 28.00
B23.	Hygrothermograph, vertical drum type, Belfort Cat. No. 5594, LESS CHART DRIVE AND CYLINDER BUT WITH (100) 176 hour charts No. 5-209-WB. Complete with pen and ink. FSN 6685-551-3188.	Belfort Instrument Company	$122.00
B24.	Model 301D Drum chart drive battery actuated, 3.0 volts D.C. for hygrothermograph-drum height 5 1/8". With power pack. Gears for 176 HOUR CHART. Not on contract. See items 18 a & b, Appendix A, for details of remote recording thermometers, which in many cases will be preferred to items B23 and B24.	Kingmann-White Inc.	$ 52.00
B25.	Instrument shelter, medium size. U. S. Weather Bureau Spec. No. 450.0615. Cotton region type.	Weather Measure Corporation	$130.00
		PRESSURE	
B26.	Precision microbarograph U.S.W.B. Spec. No. 450.7221. Chart ratio 2 1/2 to 1. Chart graduation in inches (corrected to sea level). Specify spot elevation of area where microbarograph will be operated. Complete with pen, ink, and one set of charts No. 5-1071X weekly. Spring driven chart drive. FSN 6660-551-3660	Henry J. Green Instrument Company	$353.00

ADDRESSES AND PHONE NUMBERS

Aerojet-General Corporation P. O. Box 15847 Sacramento, California 95813 Atten: Environmental Sciences Section	FTS (916) 449-2000 Ask for (916) 355-5552
Belfort Instrument Company 1600 South Clinton St. Baltimore, Maryland 21224	FTS (301) 597-3311 Ask for (301) 342-2626
Electric Speed Indicator Co. 12234 Triskett Road Cleveland, Ohio 44111	FTS (216) 522-3131 Ask for (216) 251-2540
NOAA, National Weather Service Executive Boulevard Bldg. 5, Room 627 Rockville, Maryland 20852 Atten: Mr. E. Lucas (AD 112)	FTS (301) 496-8622
G. M. Manufacturing Company 2417 Third Avenue Bronx, New York 10451	FTS (212) 460-0100 Ask for (212) 665-1601
Henry J. Green Instrument Company 2500 Shames Drive Westbury, New York 11590	FTS (212) 460-0100 Ask for (516) 333-5888
Kingmann-White Inc. P. O. Box G Placentia, California 92670	FTS (213) 836-2011 Ask for (714) 528-2111
Rex Industries 625 North 335 West Salt Lake City, Utah 84100	FTS (801) 524-5500 Ask for 328-3174
Science Associates 230 Nassau Street Box 230 Princeton, New Jersey 08540	FTS (609) 599-3511 Ask for (609) 924-4470
The Cliff Beabout Company 666 Sherman Street Denver, Colorado 80203 (Local Esterline Angus Distributor for Colorado)	(303) 244-3151

Weather Measure Corporation P. O. Box 41257 Sacramento, California 95841	FTS (916) 449-2000 Ask for (916) 481-7565
Weksler Instrument Corporation 195 East Merrick Road Freeport, New York 11520	FTS (212) 460-0100 Ask for (516) 623-0100

APPENDIX C

ANALOG WIND SYSTEM INSTALLATION AND CALIBRATION

Tower and Instrument Support for Wind System

The tower should be of sufficient height to get anemometer and vane at least 30 feet above mean maximum snow depth at the site. (See discussion in text about site selection.) A sectional TV tower, such as the Rohn Series 25 (A37) is satisfactory for most sites. The instrument supports, mounted on top of the tower, must be assembled locally from 1-5/8" galvanized pipe and fittings. Be sure to use double-weight pipe; ordinary single-weight water pipe has not proven to be durable for this support. Details and exact dimensions are not critical; see Figure 16 for general configuration.

Equipment Required:

1. Wind speed transmitter (cups and base). (Wind Speed indicator Model F420-C).

2. Wind direction transmitter (vane and base).

3. Twin-channel recorder. (Esterline Angus Model A602C).

4. Power supply calibration unit (see below under Calibration).

5. Adequate cable (at least 5 conductors, no smaller than AWG 19, external shield, or metal sheath if buried underground) laid from wind sensor site to the recording site with junction boxes, plus reserve cable to replace longest piece in the line in case of failure.

6. Rohn tower, base and guy wires (see A37).

7. Instrument support for anemometer and vane assembled from pipe fittings.

8. Properly prepared cement base with 4 bolts on which to attach the hinged base plate for the tower.

9. Multi-meter with scales 0-50K ohms, 0-6 volts D.C. (B7c)

10. A voltage divider (anemometer calibrator) with output from 0 to 4 volts. See below and Figure 17.

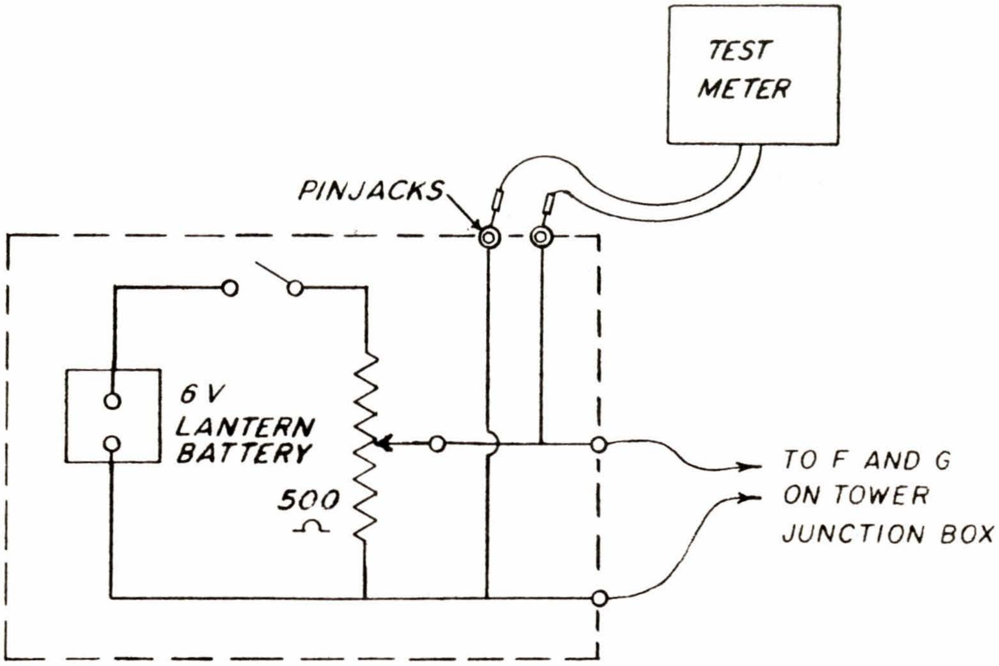


Figure 17. Schematic diagram for calibrator unit for use with analog wind system.

11. Electrician's tape, linesman's belt or equivalent, screw drivers, side cutting pliers, crescent wrench, pipe wrench.

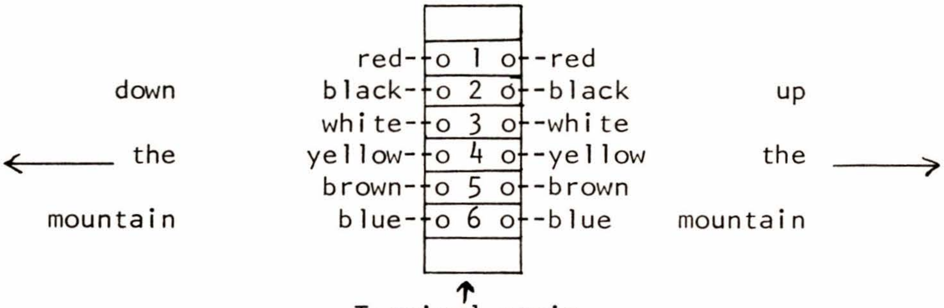
Installation Procedure:

1. Bolt tower base plate to cement base, set tower on its base, raise to position and guy tower at top and at mid height for 30' tower (at each 15' of height for taller towers).

2. Guy wire should be attached to firm anchors. Depending on soil conditions, rocks, lengths of reinforcing iron, 1/2 of railroad cross tie or other dead men can be used for anchors.

3. Install instrument supports at top of the tower.

4. Lay cable from wind tower site to recorder site. Use junction boxes at the base of the tower, every 500 to 1,000 feet down the mountain (wherever cable lengths dictate) and on the inside wall of the base area building. Keep color code consistent all the way. (See sketch below.)



Terminal strip in junction box

The actual colors will vary with the type of cable used, but when connecting wires to junction boxes be sure that the color code is followed--red to red--black to black--white to white, etc.

5. Use the ohmmeter to check the continuity of each conductor in the cable from the sensor site (top of the mountain) to the recorder (base area). Details of this step are discussed below.

6. Mount wind vane (direction transmitter) on its base and secure base to top of instrument support with set screws. Be sure the white line on the transmitter base is pointing true EAST.

7. Hook the leads from sensor into the junction box at the base of the tower. (Black wire comes from wiper; white is +, green is -.) Make notes on which wires from the sensors are hooked to which wires on the cable.

   When hooking up the recorder at the base area, be sure to follow the polarity on the recorder (i.e. hook + to + and - to -). See block diagram (Figure 19).

8. Hook the power supply-calibration module to the leads going up the mountain and to the left channel of the recorder. To be sure which wire is the wiper lead, check all three wires, two at a time with the ohmmeter while the vane is in the circuit and free to move. When two wires are found that give no meter movement, the third wire is the wiper lead. When either of the two leads being checked is the wiper lead, the variation in resistance caused by the movement of the vane will cause a slight movement on the ohmmeter.

9. Mount the anemometer on its base, secure with set screws, and run the leads from the anemometer to the junction box at the tower base. (The leads from both anemometer and vane should be securely taped to the pipe brackets and tower.) Observe polarity and note color codes as for vane. Consult Figures 18 and 19 for correct connection scheme.

Using the Ohmmeter to Check Wind Speed and Direction Cable

(Line check for continuity and shorts)

1. Study the Manual that comes with the volt-ohmmeter and learn how to zero the meter correctly and how to read the various scales.

2. Set the meter on 300 volts A.C. and check the line to be sure there is no voltage on the line. (If there is a slight voltage, shift to a lower scale to determine how great it is. The source of the current must be found and eliminated before continuing the line check.)

3. Set the meter to RX10 or low enough to read less than 1000 ohms (Ω).

4. Station a man with a 2-way radio at the top of the mountain and another at the base area with another radio and an ohmmeter.

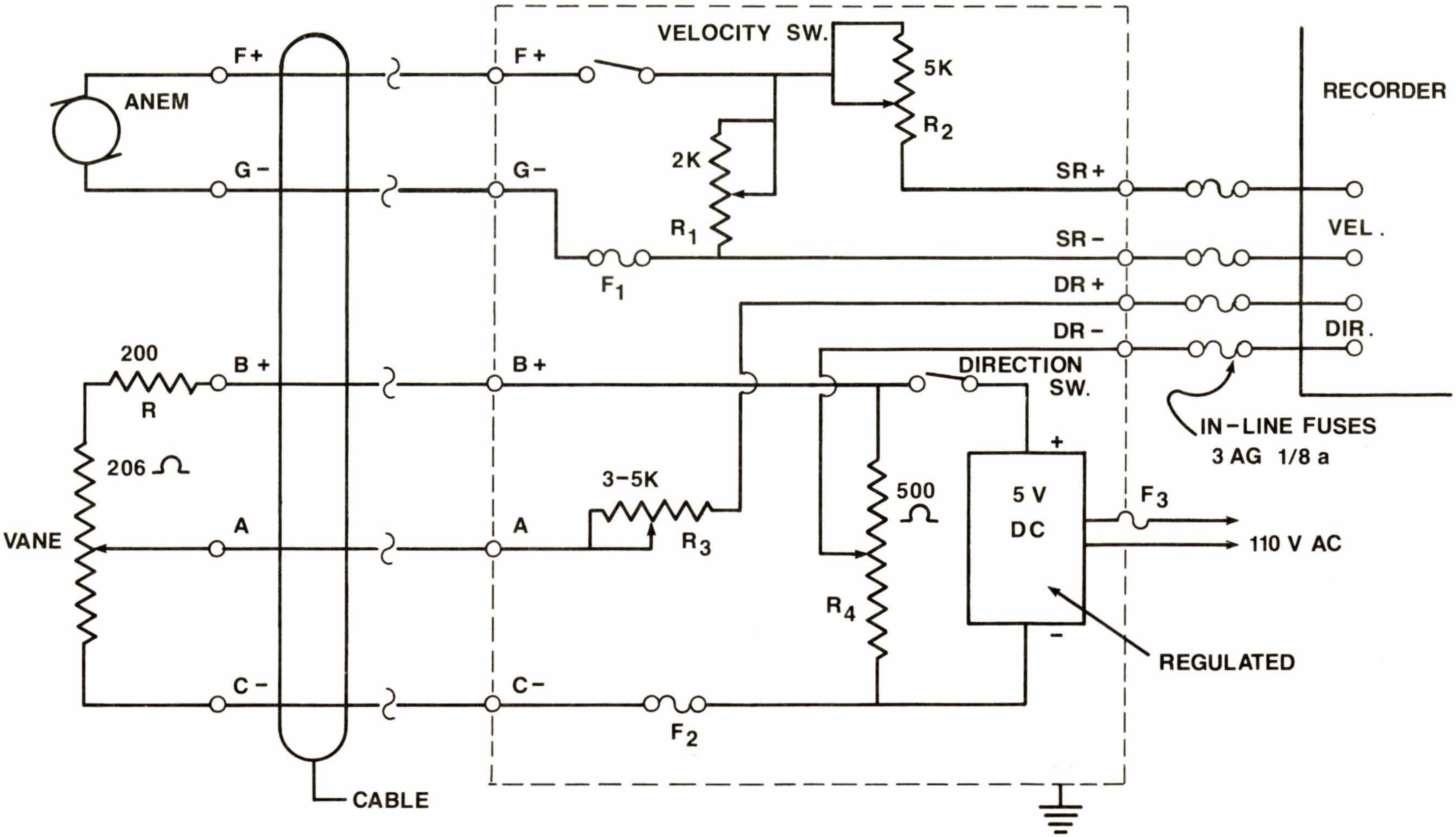


Figure 18. Schematic diagram for analog wind system.

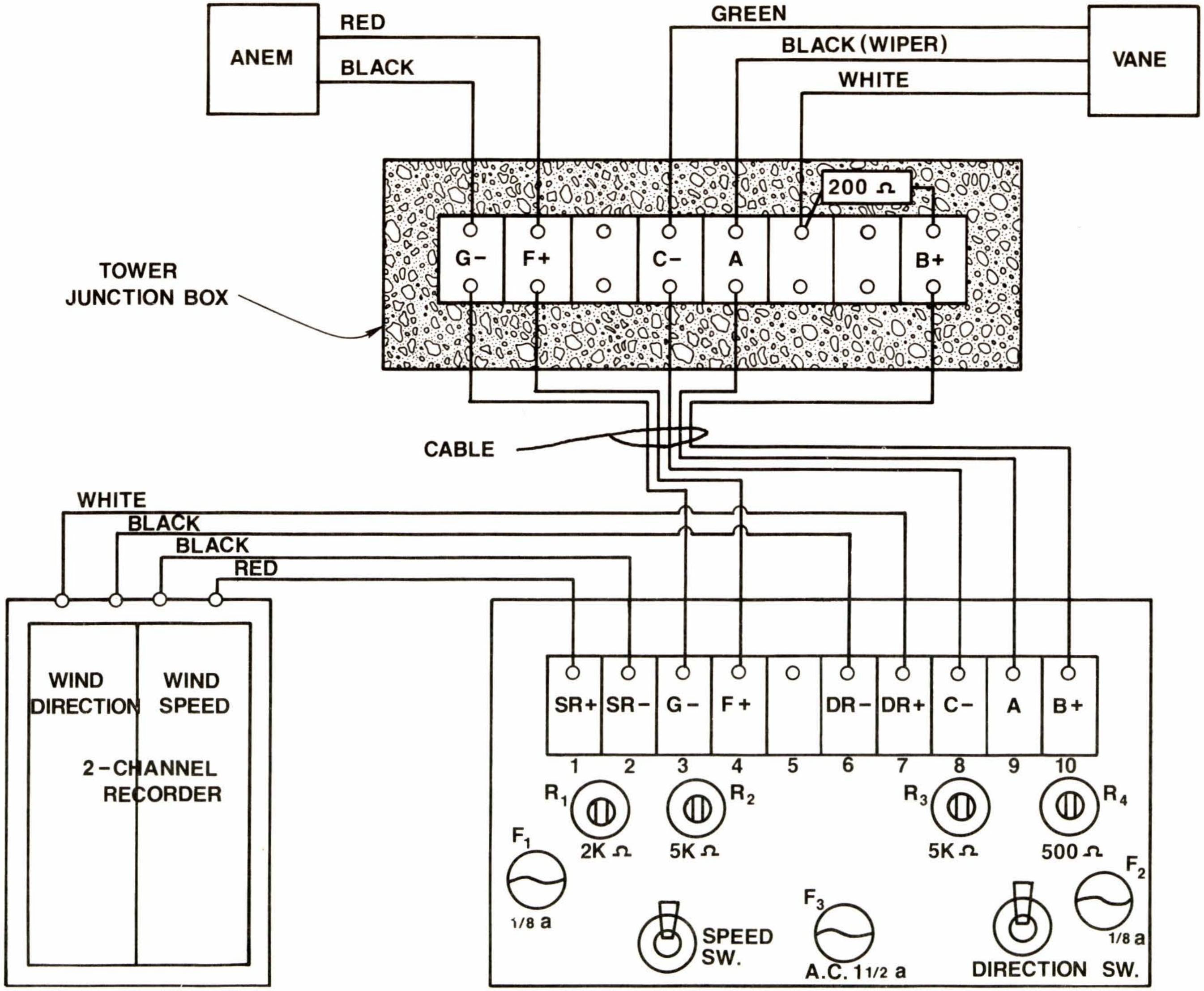


Figure 19. Block and wiring diagram for analog wind system.

5. To check the red and black wires, for example, the man at the top of the mountain shorts the red to the black wire. The other man connects the meter to the black and red wires and notes the reading from the appropriate scale.

6. If the meter shows no reading, the line is broken (open circuit). Checks must be made between junction boxes to locate the break.

7. If there had been a reading when the wires were shorted, the meter should return to zero when the short is removed. If it does not, the wires are shorted some place between the base area and the top of the mountain. Use the same method described in 5 to check between the junction boxes until the short is found and fixed.

8. If the meter returned to zero when the short was removed, leave one of the meter leads attached (for example, to the black wire) and move the other lead to another wire.

9. There should be no reading until the man on the mountain shorts the two wires being tested. After the short is made on top of the mountain, the meter reading should be recorded. It should be the same as that found in step 5. If there is a reading on the meter before the short is made on top of the mountain, there is an accidental short in the line. Record the reading and compare to the one found in step 5. The closer the accidental short is to the top of the mountain, the closer this reading will be to that for the full wire found in 5.

10. Check all the wires this way to be sure all are continuous and free of shorts.

Calibration Instructions for the Analog Wind System

These instructions assume that the Electric Speed Indicator Company sensors, properly modified, have been installed on a stout mast in a suitable location and that the appropriate cables and junction boxes have been installed to professional standards. The Esterline-Angus dual-channel 0-1 ma. recorder has been installed at the lower end of the cable, at a point where 110 volt AC commercial power is available.

A combination power supply and calibration circuit is required. This is housed in a tamper-proof steel box adjacent to the recorder and connected to a nearby 110 volt AC outlet. The circuit diagram for this unit is shown in Figure 18. As of the date of publication of this Snow Safety Guide, National Forests installing this wind system on Class A ski areas will be able to obtain a completed unit, ready for installation, by notifying the Alpine Snow and Avalanche Project, Rocky Mountain Forest and Range Experiment Station, 240 West Prospect Street, Fort Collins, Colorado 80521.

An anemometer calibrator is also required which will provide an accurate source of exactly 4.0 volts D.C. If such a source is not available locally from electronic specialists, it can be constructed according to the diagram of Figure 17.

When the lid of the power supply-calibration unit is opened, a panel will be exposed containing two toggle switches and four screwdriver-adjustable potentiometers with locking nuts. The switches turn on and off respectively the anemometer (wind speed) and wind vane (direction) circuits. Function of the four potentiometers, labelled R_1 through R_4, will be described below. The power supply-calibration unit will have been securely fastened to a wall adjacent to the recorder.

The wind speed circuit is calibrated first. Purpose of this calibration is to adjust total circuit resistance so that a 4-volt signal from the anemometer will just cause the recorder pen to move to the 100 mph mark on the chart, and at the same time insure that this resistance offers a reasonable impedance match to the anemometer. Two men are required, equipped with means of communication--usually handi-talky radios--between the anemometer mast and the recorder site. The man at the tower requires the anemometer calibrator (Figure 17) and an accurate test meter **(B7c)**.

First, make sure the two anemometer leads are disconnected from the cable at the terminals in the junction box at the tower base, and that the velocity switch is turned OFF at the calibration unit. Mechanically adjust the wind speed (left-hand) pen of the recorder, using the zero-adjust level at the base of the

recorder, until it rests on the zero line of the left-hand chart scale.

At the tower junction box, connect the test meter (ohmmeter mode) to the anemometer circuits of the cable (terminals 1 and 2). At the power supply-calibration unit, turn the velocity switch ON. Adjust R_1 until the meter reads 450 ohms. Next, disconnect the test meter, set the calibrator to about 1 volt output and connect to the terminals F+ and G- at the tower. At the recorder, connect the two wires with in-line fuse holders from the calibration unit to the wind speed terminals of the recorder (these are the terminals for the right hand recorder channel). If the right hand recorder pen deflects part way across the chart, proceed. If not, and the pen deflects to the left, reverse the two wires to the recorder.

Next, set the output of the anemometer calibrator to exactly 4.0 volts. When this has been confirmed between tower and recorder sites, the man at the recorder can then adjust R_2 until the recorder pen deflects exactly to 100 mph on the chart. Readjust R_1 slightly if necessary to obtain proper deflection of the pen. When these adjustments are completed, use a wrench to tighten the lock nuts on R_1 and R_2. The velocity calibration is now complete. Reconnect the anemometer wires at the tower junction box to give normal deflection of the wind speed recorder pen.

The direction calibration also requires two men with communication between tower and recorder. In this case the man at the tower has to climb it and position himself where he can both swing the wind vane and operate his radio. Mechanically zero the direction (right-hand) pen of the recorder. With the direction switch OFF, turn R_3 all the way counterclockwise and R_4 all the way clockwise. Make sure the vane body is positioned with the white mark pointing east and point the vane parallel to the white mark (at the vane resistor cross-over point). Connect the two direction wires with in-line fuses to the direction terminals (for the left-hand channel) of the recorder and turn the direction switch ON. The left-hand recorder pen should deflect to the right; if it deflects to the left, reverse the wires to the recorder. Carefully adjust the vane position for minimum pen deflection (adjust to low side of the cross-over point). If little pen deflection occurs, turn R_3 until it deflects. Turn R_4 until the pen returns to zero on the chart. This balances out the line resistance in the wind vane bridge circuit. Now swing the vane to the position of maximum pen deflection (high side of cross-over point). Move the vane very slowly to achieve maximum pen deflection. Holding the vane in this position, adjust R_3 until the pen reads full-scale on the chart. The direction calibration should now be complete. The directions on the chart, equally spaced from zero to full-scale, should now be East,

South, West, North and East, in that order. Box the compass with the vane to confirm this. If the directions do not appear in the correct order as the vane is swung, reverse the cable connections to terminals C+ and B- of the power supply-calibration unit and repeat the calibration procedure. The 200 ohm resistor, R_5, in series with the vane is necessary to assure linear response of the recorder. It should be mounted on the terminal strip in the tower junction box.

APPENDIX D

NOTE ON MEASUREMENTS

Practically all measurements made for scientific purposes in the world today are made in metric units. The modern standard of metric measurement is the SI system of units (Systéme International d'Unités). Details of this system are set forth in the Royal Society publication listed in the bibliography.

The metric system is also the dominant one for industrial and everyday use in most of the world. Its use is steadily expanding. The United States today remains the only major country in the world devoted to the English system of measurements and even here the metric system is an officially recognized standard. England has now opted for conversion to the metric system, so the term "English system" will no longer be applicable. (One cynical observer has noted that there are now only two systems of measurement in use---medieval in the United States and metric in the rest of the world.)

It is inevitable that the English (or medieval) system of measurement eventually will be replaced by the metric one in the United States. Use of the latter is steadily expanding (e.g.--length of cigarettes in millimeters) in areas of public as well as scientific interest. The severe limitations of the English system are obvious---try, for instance, to compute snow density in slugs per cubic foot from measured depths of snow and water content in inches. We earnestly hope that snow, weather and avalanche observations will be among the earliest to be converted entirely to the metric system in this country.

In the meantime, such observations straddle the English and metric systems in schizophrenic fashion. Snow profile measurements, for instance, are firmly planted in the metric system because they are keyed to the centimeter scale of the ram penetrometer. Snow densities are always reported in metric units by even the most ardent devotees of the English system. On the other hand, the skiing public customarily expects snow depths to be reported in inches and temperatures in degrees Fahrenheit. Because snow rangers exist in the first place to serve the interests of public safety and information, these quantities are recorded in inches and degrees Fahrenehit. A dual system is thus inevitable today. For the present we can only recommend in the strongest possible terms that as many observations as possible be made and reported in metric units. Those which are frequently disseminated to the public, such as air temperature, snow depth or wind velocity, will have for the present to continue in the English system.

For convenience of the man in the field who has to live with the confusion of two systems, the following table has been compiled as a ready reference for commonly used units of measurements and desired accuracies of observation as applied to operations on U. S. Forest Service Class A ski areas.

TABLE I

Element Observed	Instrument	Units	Typical Range	Accurate to Nearest
Wind velocity	anemometer	miles per hours	0-120 mph	2 mph
		meters per second	0-50 m/s	1 m/s
Wind direction	vane	degrees azimuth	0-360°	20°
		16 compass points	compass box	compass point
Temperature (snow & air)	thermometer thermograph	°F °C	-40° - +70° -40° - +20°	1° F 0.5° C
Humidity	hygrograph	% rel. humidity	10% = 100%	10%
	sling psychrometer	dew point, °C	-40° - +20°	1° C
Cloud cover	eyeball	1/8's of sky	0/8 to 8/8	1/8
Total snow depth	master snow stake	inches	0-150"	1"
		centimeters	0-400 cm	2 cm
New snow depth	portable snow stakes	inches	0-36"	0.5"
		centimeters	0-90 cm	1 cm
Precipitation	precipitation gage snow core	inches & hundreths millimeters	0 - 3.00" 0 - 75 mm	0.01" 0.5

TABLE I (continued)

Element Observed	Instrument	Units	Typical Range	Accurate to Nearest
Snow density	sample tubes and balance	kilograms per cubic meter	20-500 kg/m^3	10 kg/m^3
Snow grain size	hand lense & reticle	millimeters	0.5 - 2.0 mm	0.5 mm
Slope angle	clinometer	degrees (never %)	0 - 90°	1°
Fracture line height	tape or ruler	feet	0 - 12'	1.0' estimated 0.1' measured
		meters	0 - 4 m	0.3 m estimated 0.05 m measured
Avalanche dimensions or distance run	estimation topographic map tape	feet meters	0 - 5000' 0 - 1500 m	100' 30 m
Altitude	altimeter topographic map	feet meters	3000 - 12,000' 1000 - 4000 m	map contour interval

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